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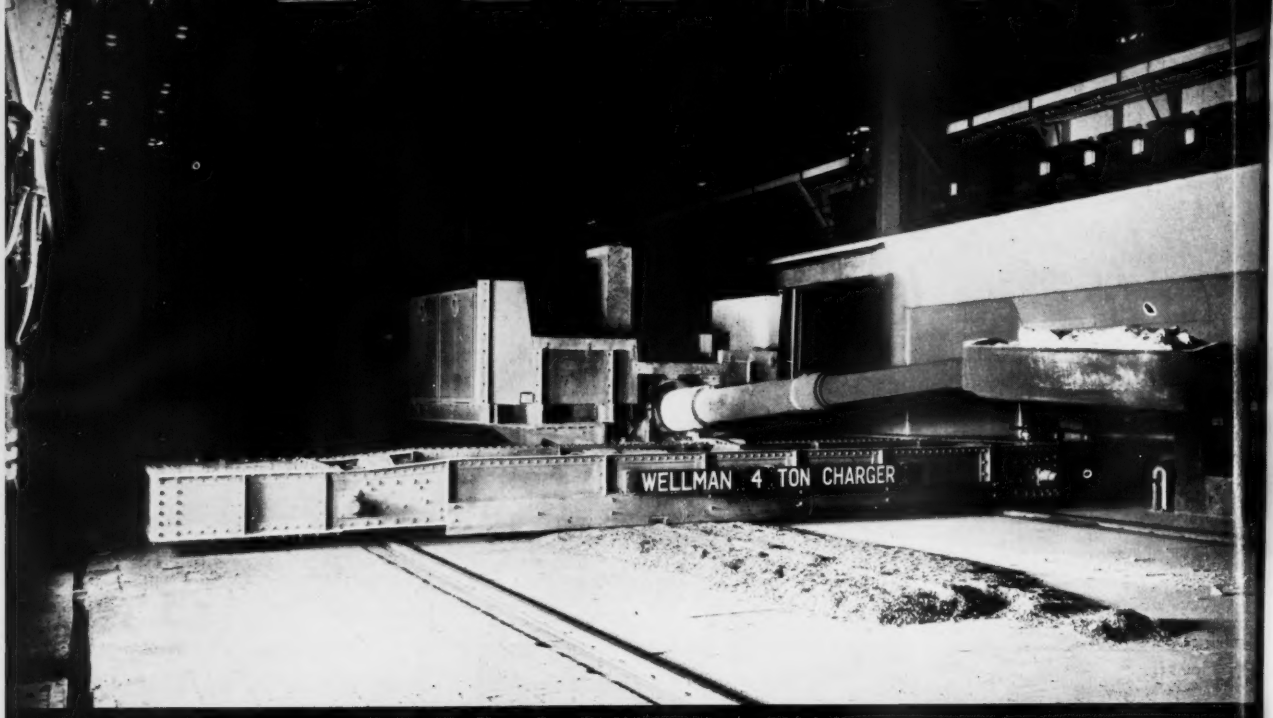
WELLMAN



Britain's Steel . . .

The maintenance of high standards of engineering technology coupled with the introduction of many recent advances in metallurgical practice has assured a leading place in the markets of the world for products made from Britain's Steel.

A noteworthy contribution to this great achievement has been made by the Wellman Organisation which, for over fifty years, has specialised in the design and construction of Steelworks Plant.

This long experience, enriched by intimate association with American and Continental Steelmaking practice, places Wellman Engineers in an unrivalled position to design and erect equipment ranging from the smallest units to complete Steelworks installations.

THE WELLMAN SMITH OWEN ENGINEERING CORPORATION LIMITED

PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1 — WORKS: DARLASTON, SOUTH STAFFS

SIR ANDREW McCANCE, D.Sc., F.R.S.

SIR ANDREW McCANCE, Deputy Chairman and Joint Managing Director of Messrs. Colvilles, Ltd., was born in Cadder, near Glasgow, fifty-eight years ago. He received his early education at Morrison's Academy, Creiff, at Allen Glen's School, Glasgow, and his scientific education at the Royal School of Mines, London. He first became associated with Scottish Industry in 1910, when, on leaving the Royal School of Mines, he went to the Parkhead Works of Messrs. Wm. Beardmore and Co., Ltd., as metallurgist, being appointed assistant armour manager a year later.

At the early age of 24, following a paper to the Institute, entitled " A Contribution to the Theory of Hardening," Sir Andrew received the degree of Doctor of Science of London University. In 1919 he founded and became Managing Director of the Clyde Alloy Steel Co., Ltd., and was also advisory metallurgist to Messrs. David Colville and Sons, Ltd., the Board of which he was invited to join in 1930. When the new public company of Colvilles, Ltd., took over the business of the older private limited company, Sir Andrew continued as Director and General Manager. He has since been identified with all the technical developments of Colvilles, including the first Scottish integrated steelmaking unit at Tollcross and Clydebridge which was brought into operation in 1939. In May, 1944, he was appointed Deputy Chairman and Joint Managing Director of the company. He is also a Director of the Steel Company of Scotland, Ltd., the Lanarkshire Steel Co., Ltd., Messrs. Smith and McLean, Ltd., and Messrs. Bruntons (Musselburgh), Ltd.

In 1943, Sir Andrew was elected a Fellow of the Royal Society, and was the first Chairman of the British Iron and Steel Research Association. He is also a Fellow of the Institute of Physics and a Past-President of the West of Scotland Iron and Steel Institute.

In 1914 Sir Andrew was elected a Member of The Iron and Steel Institute ; he became a Member of Council in 1932, and a Vice-President in 1941, and in 1940 he was awarded the Bessemer Gold Medal in recognition of his outstanding services in the application of science to the iron and steel industry. He took office as President of the Institute at the recent Annual General Meeting on 5th May, 1948. The honour of knighthood was conferred upon him by the King in June, 1947.

He is the author of a number of technical papers, of which those to the Faraday Society established the principles of balanced reactions in the manufacture of steel. These he applied to the open-hearth process as far back as 1918 with outstanding results.

Sir Andrew McCance, D.Sc., F.R.S.
President of The Iron and Steel Institute

PROCEEDINGS OF
THE INSTITUTE

REPORTS OF COUNCIL - OFFICIAL NOTICES

Presidential Address

THE DEVELOPMENT OF THE OPEN-HEARTH FURNACE

By Sir Andrew McCance, D.Sc., F.R.S.

I am very conscious of the distinction conferred on me by the invitation to occupy the Presidential Chair of this Institute and I have to thank the Council and the Members for this mark of their confidence. It would afford me much satisfaction if during my term of office I could in any way further the work which this Institute during its long history has always so actively promoted for the benefit and advancement of our great industry.

The greatness of the iron and steel industry has been built up by the united efforts of many men working in diverse fields, but one common principle has always determined whether the results of such work were accepted or not into the storehouse of industrial experience—that of economic advancement. New methods and new materials have to achieve some purpose not hitherto possible or they have to achieve old purposes with greater economy.

In the methods of steelmaking there have been no basic changes since the outstanding inventions of Bessemer and Siemens and progress has followed the line of an ever greater economy through ever greater production or productive efficiency. I have thought that it might be of interest if I outlined some of the prominent features in this development of the Siemens open-hearth furnace as a productive unit and touched on some of the things concerning it in which I have always been interested. And if my mind particularly deals with cold-metal practice I give as the reason (and not as an excuse) that the part of the country from which I come has devoted much energy and thought to the development of steelmaking from scrap and cold pig iron.

All inventions are the products of the period in which they are discovered—they are merely the escarpments in the advancing front of collective thought. The invention of the regenerative furnace is a typical instance of this. It was the outcome of two lines of thought which converged—the better understanding of the nature of heat which followed the work of Joule and Clerk Maxwell, and the desire to produce steel in larger quantity. If Siemens had not been interested in the first he would probably never have given any thought to the latter.

THE crucible steel process invented by Huntsman in 1740 was the first practical and commercially successful method for making steel from cold charge by melting and it inevitably led to a substantial expansion in the demand for steel as new applications and uses were found for it—an expansion of the newly created steel industry which progressed steadily for nearly a century.

It was an industry of fine steels for toolmaking and the like and it was not until the advent of the railway age during the second quarter of the last century that a vision of the production possibilities of steel for engineering construction entered men's minds. For the first time the limitations in the maximum weight

This Address was presented at the Seventy-Ninth Annual General Meeting of the Institute, on 5th May, 1948, with the retiring President, Dr. C. H. Desch, F.R.S., in the Chair.

Sir Andrew McCance is Deputy Chairman and Joint Managing Director of Messrs. Colvilles, Ltd., Glasgow.

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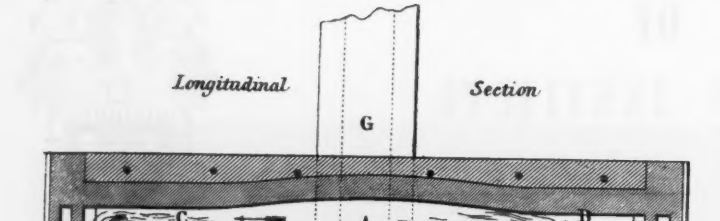


Fig. 1—Siemens' first regenerative furnace

that could be handled in crucibles began to be realized and once the problem was defined there was no lack of ideas to surmount or of inventors to grapple with the situation which presented itself.

Since it was impracticable to enlarge the size of crucible which could be made successfully in refractory clay, the first efforts were directed along the line of multiplying the number of crucibles which could be accommodated in one furnace at a time—a method which found greater favour in other countries, particularly in U.S.A., than in Britain.

The alternative idea of doing away with the crucible altogether and of carrying out the crucible process of making steel in a furnace hearth that was open to the heating flames seemed to have occurred to many people during the period between 1840 and 1860. The names of Heath, Attwood, Sudré, Gentle Brown, Parry, Chenot, and others occur frequently in the technical literature of these days but their names and their processes have alike been forgotten as the penalty of their unsuccess.

As so often happens in the history of invention the path of progress for the steel industry was created by a man who was not primarily interested in steel manufacture. William Siemens had taken up permanent residence in this country in 1844, and his earliest interests were in electrical and mechanical engineering like those of his elder brother, Werner Siemens, who founded the firm of Siemens and Halske.

Siemens was a man who possessed a truly scientific outlook and he took great interest in all the scientific developments of his time which was indeed a period of giants, for Joule, Clausius, and Clerk Maxwell were actively creating the foundations of the dynamical theory of heat on which all modern scientific thought is founded. The problems of heat conservation and economy were constantly in his thoughts and in those of his famous contemporaries with many of whom he was in friendly contact.

It was a year after his arrival in this country that there was brought to the attention of the Institution of Civil Engineers by the Rev. Dr. Stirling, a minister of Galston, near Kilmarnock, a heat exchanger which he had patented in 1817 and which he termed "a regenerator." Stirling had spent many years trying to perfect a hot-air engine with very little success, the engineering facilities available not yet having reached that state of perfection which was really prerequisite to the success of his idea.

However, it is on record that a hot-air engine constructed according to his invention as ultimately developed was installed in a Dundee foundry in 1842 and worked for several years quite successfully.

Siemens acknowledged his indebtedness to Stirling for the idea of regeneration and his first application was in a regenerative condenser which was applied to achieve greater heat economy in the steam engines then in use.

This first attempt was only a qualified success owing to engineering difficulties and it was soon forgotten. His second application was to the heating of billets in the ironworks of Marriott & Atkinson in Sheffield—an application suggested by his brother, Friedrich Siemens, which was an immediate success and resulted in a saving of 70–80% of the fuel previously required for this purpose. This furnace, patented in 1857, used solid fuel which was burned in two hearths on either side of the heating chamber and over which passed the air which had been preheated in the now familiar checker chambers (Fig. 1).

It is recorded that at these Sheffield works the furnace was also used to melt steel in crucibles and it was no doubt the difficulties which showed up in these trials that directed Siemens' attention to the problems of steel melting. At any rate he came up against serious difficulties when this type of furnace was applied to puddling or to steel melting and it was only after his invention of the gas producer and his second patent of 1861 that the regenerative furnace as we now know it came into its own and that claims in regard to steel melting were made.

But while the new design of furnace was a success, his steelmaking troubles were by no means over. He had the misfortune to give licences to people with no great perseverance and in his own words, "Although two of my earlier licensees, Mr. Chas. Attwood of Tow Law and the Fourchambault Company in France (with whom was my esteemed friend the late M. le Chatelier, the Inspecteur Général des Mines) succeeded in 1865 and 1866 in producing steel upon the open hearth, they did not persevere sufficiently to attain commercial results."

There is no doubt that part of these difficulties arose from metallurgical causes, for Siemens' earlier endeavours were directed towards making steel by oxidizing molten pig iron with iron ore, and the duration of his process coupled with the then uncertainties of furnace-temperature control, led to failure of the brickwork. These failures had a bad effect on his chances of success which were still further depressed

by the failure of a pirated design of regenerative furnace installed at Woolwich Arsenal but with which he had nothing whatever to do. Indeed he had such difficulty in getting people interested in his process that on his own account he was forced to start the Sample Steel Works at Birmingham in 1865 for demonstration purposes. This was at first a crucible steelworks but in 1867 an open-hearth furnace was added.

In the meantime the whole outlook for open-hearth steel had been changed by Pierre Martin at Sireuil; he had taken out a licence in 1864 and by diluting the carbon in the pig iron with wrought-iron scrap before starting to remove it with ore and by the use of a silica-sand bottom, had quickened up the process and produced good quality steel in a furnace of 1-ton capacity. Martin took out a patent for his process in 1865 but its validity was immediately challenged by many who claimed to have anticipated it and after some years of lawsuits which exhausted his resources he retired from the steel trade, which he had helped to create, a disappointed man. No recognition was given to him until his long life was nearly over and his gratification at receiving the Bessemer Gold Medal from this Institute in 1915 came to him only a few days before he died at the advanced age of 91.

While the success of the pig-iron/scrap process was undoubtedly the foundation of Siemens' own success as well, he continued his endeavours to use his furnace for the direct production of steel from ore. It was through this in fact that Siemens' steelmaking came to Scotland.

The Tharsis Sulphur and Copper Company had large stocks of burnt pyrites or "blue billy" in Glasgow and they took out a licence in 1866 for a process of Siemens for reducing ore in a rotary furnace and thereafter melting the iron sponge in an open-hearth furnace, the operations being carried out at the works of Rowan and Company. These initial attempts were not successful and were soon abandoned, but they seemed to have impressed Sir Charles Tennant and the other promoters of the venture, for soon after, in 1871, the Steel Company of Scotland was formed to further the same idea, Sir Charles Tennant being the first Chairman. In addition to four open-hearth furnaces of 4–6 tons capacity for making steel the company started out with a Siemens rotary furnace for the direct reduction of ore and a contract to purchase from the Tharsis Company 20,000 tons of "blue billy" at 25*s.* per ton. The direct process was again a failure but the cold-metal process thus introduced to Scotland progressed and has been developed by succeeding generations of steelmakers in a manner that merits some record.

The reason why cold-metal practice was specially appropriate to Scottish conditions was due to the limited native ore deposits and the need to import a large proportion of the blast-furnace ore, together with the presence of large consuming industries like shipbuilding and engineering which were scrap producers. At the same time a substantial export of finished steel was carried on and acquaintance with foreign trade and connections and with shipping interests directed attention to the possibilities of scrap importation which was developed in a large way. Even in the years between 1930 and 1940 the Scottish market took 50–60% of all the steel scrap imported into the United Kingdom.

THE GROWTH IN FURNACE CAPACITY

When Siemens started his Sample Steel Works at Birmingham in 1865 for making steel to demonstrate the success of his regenerative furnace, his one demonstration model had a capacity of 24 cwt. At Landore and later at the Hallside Works of the Steel Company of Scotland the furnaces had capacities of 4–6 tons although within a few years larger furnaces of 10–15 tons were constructed which produced 150–180 tons per week.

At this stage, however, there was a pause in the rate of growth of furnace capacity undoubtedly occasioned by the desire to gain experience both in the engineering construction of steelworks plant and in the metallurgical control of steelmaking operations. There was no lack of inventiveness in creating new designs of handling equipment nor lack of variety in the methods proposed for dealing with these larger quantities of liquid steel, but the state of the art was still dominated by the principles which Bessemer had introduced in the layout of his own works for the same purpose.

The charging of all furnaces was carried out by manual labour and it was accepted that on the average a 10–15-ton furnace was a large enough proposition to tackle by hand charging.

It was not until the period 1885–1895 that the mechanical equipment of open-hearth plants began to take on its own individual characteristics, and melting shops began to assume that appearance which is now so familiar, for it has changed little since then.

The first step in this new progress was the mechanical charger, introduced almost simultaneously by Wellman in U.S.A. and at Witkowitz in Austria. Originally worked hydraulically it was changed within a few years to electrical operation. Mechanically operated doors and rather surprisingly the water-cooling of doors were rapidly introduced into American designs which originated during this period. In considering the much slower introduction of such mechanical aids to production into British works, it must not be forgotten that American climatic conditions played no small part in their speedier adoption in that country, the hotter summers making the heavy work of charging furnaces very exhausting.

It was stated at the time that the introduction of mechanical charging increased the output by 11% over that with hand charging.

The effect of these improvements was soon noticeable and furnace capacities began once more to increase, the average size at the beginning of the century being 30–40 tons although larger furnaces had also been built.

While the tendency of the times was towards expansion, the gain in production from the increase in capacity was as yet doubtful since the smaller furnaces of 20–25 tons were giving in proper hands four charges per day against two charges per day from

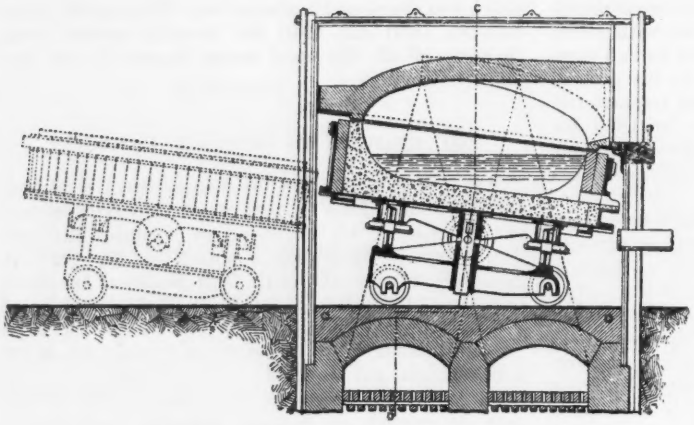


Fig. 2—Pernot's open-hearth melting furnace

a 50-ton furnace. This situation arose from the fact that in their application the principles of combustion were not as yet understood and the larger furnaces were relatively less efficient in this respect than the furnaces of smaller capacity.

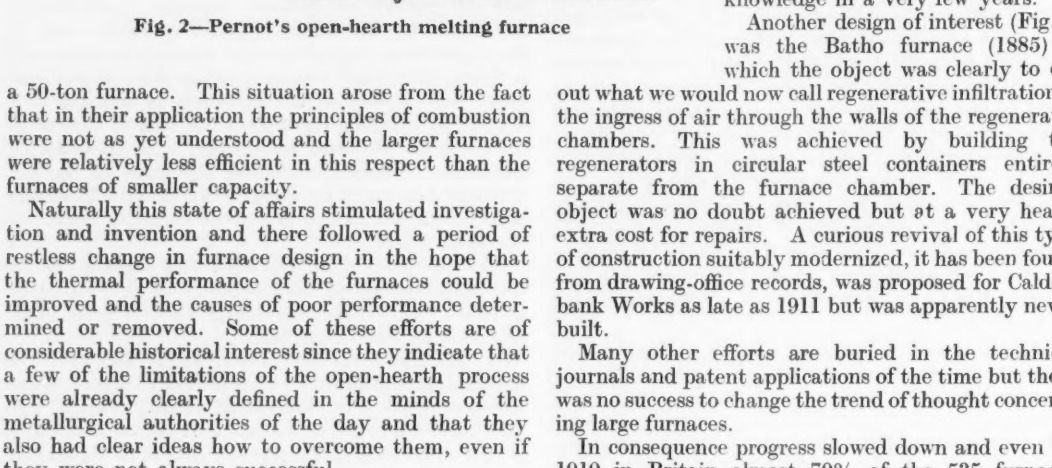
Naturally this state of affairs stimulated investigation and invention and there followed a period of restless change in furnace design in the hope that the thermal performance of the furnaces could be improved and the causes of poor performance determined or removed. Some of these efforts are of considerable historical interest since they indicate that a few of the limitations of the open-hearth process were already clearly defined in the minds of the metallurgical authorities of the day and that they also had clear ideas how to overcome them, even if they were not always successful.

Take as an example the Pernot furnace (1877) (Fig. 2), in which the hearth rested on a trolley which could be moved to facilitate repairs and could also be made to rotate. The purpose of the rotation was to agitate the bath as in the Bessemer process and so speed up the chemical reactions—a definite acknowledgment of the value of increasing the surface of slag–metal contact, an idea later carried to its logical conclusion by Perrin. It is reported that furnaces built to this design gave good outputs and service but it is not difficult to imagine the reasons why they faded out of our knowledge in a very few years.

Another design of interest (Fig. 3) was the Batho furnace (1885) of which the object was clearly to cut out what we would now call regenerative infiltration—the ingress of air through the walls of the regenerator chambers. This was achieved by building the regenerators in circular steel containers entirely separate from the furnace chamber. The desired object was no doubt achieved but at a very heavy extra cost for repairs. A curious revival of this type of construction suitably modernized, it has been found from drawing-office records, was proposed for Calderbank Works as late as 1911 but was apparently never built.

Many other efforts are buried in the technical journals and patent applications of the time but there was no success to change the trend of thought concerning large furnaces.

In consequence progress slowed down and even by 1910 in Britain almost 70% of the 535 furnaces



SECTIONAL ELEVATION.

Fig. 3—Batho Furnace

existing were still of 40 tons capacity or less while in Germany the preference for the smaller furnace was such that 87% of the then existing units were less than this.

Faith in the benefits arising from large capacity was not completely dormant, however, for D. Colville built in 1908 acid furnaces of 100 tons from which an output of 1100 tons per week was obtained and in America a furnace of 160 tons had made its appearance. Effort was concentrated on the combustion problem and many new designs of port were tried out, some of which like the water-cooled port have now become standard practice.

It was not until after the first World War that the benefits from these technical improvements in construction and practice were realized, for by that time economic conditions and high labour costs together had made more intensive production from steel furnaces and rolling mills an imperative necessity. No better illustration of the results from this continued effort in cold-metal practice can be given than that published by Gibson in his contribution to the Symposium on Steelmaking organized by the Institute in 1938, and his table of average outputs per furnace in succeeding years is here reproduced* :

Year	Av. Weekly Output per Furnace, Tons	Av. Charge Weight, Tons	Year	Av. Weekly Output per Furnace, Tons	Av. Charge Weight, Tons
1918	541	64	1933	1171	88·6
1919	537	54	1934	1165	90
1920	679	70	1935	1155	89·7
1921	734	73	1936	1172	89·9
1922	841	76	1937	1230	89·9
1923	850	78	1938	1205	88·6
1924	860	78	1939	1248	88·7
1925	872	82	1940	1100	87·7
1926	868	84	1941	1046	86·7
1927	916	84	1942	977	85·5
1928	980	83	1943	1024	86·3
1929	985	86	1944	1033	86·6
1930	1070	88	1945	1041	86·9
1931	1103	88·8	1946	1115	87·1
1932	1090	88·6	1947	1216	87·1

The limit to the charge weight in this table was determined by the capacity of the ladle crane in the casting pit, but in spite of this limitation the output of a 90-ton furnace has continually been improved excepting during the years of war, and today it is reckoned that given reasonable pig iron and scrap such a furnace should give 1500 tons in a continuous working week.

The progress of production in these recent years has already been reviewed in detail—particularly by the Open Hearth Committee of the Iron and Steel Industrial Research Council in their report of 1938—so that there is no need to repeat what has been done so well by that Committee.

FURNACE DIMENSIONS

It must be admitted that the design of melting furnaces is still entirely empirical and based on experience, and that even the practical rules used by furnace builders to determine the dimensions for a specified furnace capacity show considerable diversity when compared with one another. There is little room for variation in the determination of the cubic capacity of a bath to hold a given weight of steel, but thereafter the area of the bath is generally fixed by allotting anything from 2 to 6 sq. ft. of hearth area per ton of steel, or by the inverse process of first fixing the depth of the bath from previous experience of the behaviour of similar furnaces. In either case there is ample latitude for exercising individual judgment and few of us have not experienced the disappointment of building furnaces whose performances fell short of expectations.

The practical relation where there is least disagreement is the ratio of length to breadth of the bath and for most modern furnaces this lies between 2·8 and 3·0. It is controlled by the burning characteristics of the gas flame and limited by the desire not to have too long a travel of the charging-machine ram and consequently not too broad a furnace chamber within which the ram and box have to work.

It is accepted that the depth of the bath is an important factor in determining the production rate since heat is transmitted to the charge mainly through the upper surface by radiation from the furnace walls and flame.

With this in mind it is a simple matter to deduce a rational basis for dimensioning the hearth by purely dimensional reasoning. The principle could be called that of thermal similarity in which the time to reach a stated temperature at the lowest point of the hearth would be the same for all furnaces irrespective of their charged weight.

The charge can be compared to a flat slab of thickness d which is absorbing heat at a constant rate from its upper surface. The heat will flow in from the surface and will create a temperature distribution within the slab which will be constantly changing but at any instant there can be mapped out the contour line for a given temperature T_1, such for instance as a temperature near the melting point of the material of the slab itself.

From the theory of heat conduction the temperature distribution for such a slab can be represented by $F(x/\sqrt{kt})$, where x is the distance from the surface, k is the diffusivity and t is the time, and if we are concerned only with the temperature at the under surface of the slab at time t_1, this will be the same for all slabs so long as $d/\sqrt{kt_1}$ is constant.

If the duration of a charge is to be independent of the size of the furnace, the rate at which heat is supplied to the furnace chamber must be proportional to the weight of the charge since the heat consumption per ton is constant. The time required to reach comparable states of temperature distribution must therefore bear a fixed proportion to the total duration of the charge or what is more readily obvious, must result from the absorption of a fixed proportion of the total heat supplied. The condition of thermal similarity that $d/\sqrt{t_1} = \text{constant}$ requires in consequence that $d/\sqrt{W} = \text{constant}$ (where W is the charge weight), that is :

$$\text{Depth of bath} \propto \text{hearth area} \propto \sqrt{W}$$

and

$$\frac{\text{Hearth area}}{\text{Depth of bath}} = \text{constant}.$$

* *The Iron and Steel Institute*, 1938, *Special Report No.* 22, p. 28.

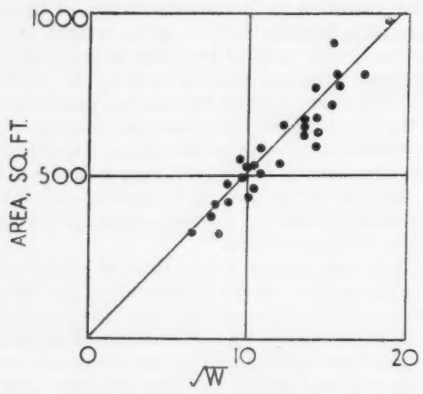


Fig 4—Relation between furnace capacity (W) and hearth area (A)

While the argument has necessarily been simplified by assuming that the bath of an open-hearth furnace can be compared in its thermal behaviour to a parallel slab, it is interesting to find that by plotting the hearth area (distance between blocks × distance between walls) of a number of British, American and Continental furnaces against $\sqrt{W}$ it can be confirmed that this rule arrived at by purely dimensional reasoning is substantiated from experience with furnaces ranging from 40 to 350 tons capacity. The straight line through the points in Fig. 4 gives :

$$\text{Hearth area} = 51\sqrt{W}$$

The average depth can be expressed by a similar relation but once the hearth area has been found the value for the depth can be more conveniently determined from the volume equivalent of the capacity after finding the true area of the bath from the drawing.

Furnaces designed on this basis should give a production proportional to their capacity. The Open Hearth Committee in 1938 rated furnaces according to their hourly production rate per 100 tons of capacity, but this is merely equivalent to the number of casts per week. On a continuous week of 168 hr. if N charges are obtained the hourly rate will be $NW/168$, and if this is expressed per 100 tons of capacity :

$$\text{Hourly rate per 100 tons capacity} = \frac{NW}{168} \Big/ \frac{W}{100}$$
$$= \frac{N}{1{\cdot}68}$$

An hourly rate of 10 tons is equivalent to 17 casts per week—by no means an impossible figure. There are 225-ton furnaces in America using oil-firing and 52% of hot metal giving this result, and a 90-ton gas-fired Venturi furnace with cold charging at Glengarnock has also reached this target when scrap was of better quality than it is unfortunately today.

But it must be admitted that with the large tilting furnaces which are necessary for working the high-phosphoric pig irons of Britain such a high rate is unattainable at the present time. Nevertheless the mere possession of a target figure has usually been in itself a sufficient incentive to technicians.

ASSEMBLY OF RAW MATERIALS

The problems of organization in cold-metal shops centre round the supply and handling of the pig iron and scrap and the correct timing and sequence of these operations.

A popular construction for such a shop in this country places the pig-iron and scrap marshalling bay immediately behind and parallel to the open-hearth bay. The scrap, etc., is handled by magnets and is dropped into the charging boxes situated on a fixed bench in the marshalling bay and immediately in front of the furnaces. For minimum operating time the top level of the wagons in which the materials are delivered to the marshalling bay should be level with the tops of the charging boxes as they rest on the bench. This necessitates a lowering of the railway level but it has the great advantage that the magnet lift is reduced to a minimum, while, when over the charging box, it gives a minimum fall for the scrap into the box, which means not only a saving in operating time but also a saving in wear and tear.

Magnet cranes for this service must be built more than usually strongly and have powerful motors. Their maximum rate of length or cross travel is not of such importance as their powers of acceleration, for the movements at work are restricted to short distances for speedy handling. There are few existing cranes in Colvilles, Ltd., which have not had their motors replaced with larger units since they were first installed in an endeavour to quicken the filling of boxes.

This in turn has created another problem, for with

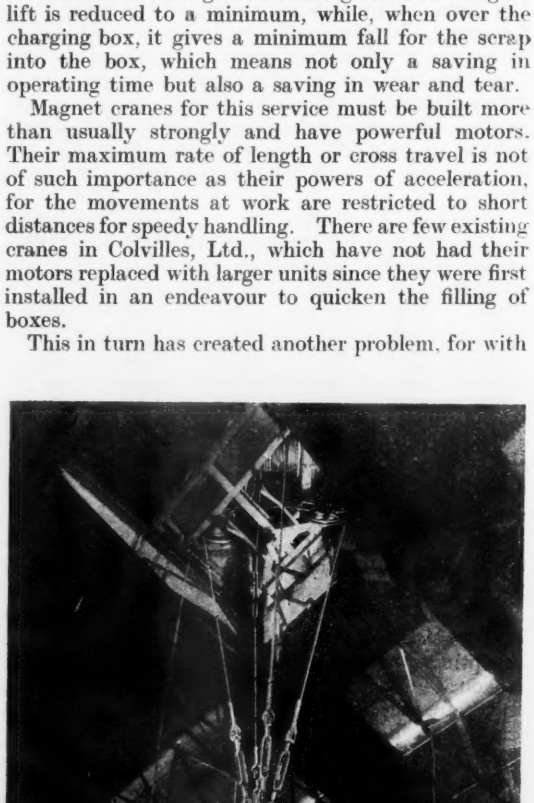


Fig. 5—Four-rope non-swinging magnet crane

rapid starting and stopping the swinging of the magnet is greatly increased and control by the operator requires more skill if the time saved is not to be lost again waiting for the magnet to steady. Swinging is inevitable with a single rope, and after carrying out experiments with models, a four-rope magnet crane was designed which has proved successful in appreciably reducing magnet swinging during operation.* This departure from orthodox practice is illustrated in Fig. 5.

With the layout described above, each open hearth in a shop has allotted to it a length of charging-box bench equal to the furnace spacing. At the commencement of charging this bench can be assumed full of filled boxes, and during the time taken to charge these boxes into the furnace the empty boxes should be refilled. With quick-acting furnaces, and particularly with light-grade scrap this requirement places a definite limit on the size of the furnace for which such a layout is efficient. As furnaces get larger and scrap gets lighter a separation of the marshalling bay from the furnace bay becomes absolutely necessary, so that the larger number of scrap boxes required can be serviced by several cranes and the time of refilling curtailed.

A change in operational method follows in consequence, for if boxes on bogies are to be run into the furnace shop they can just as readily be placed immediately in front of the furnace and charged with a single cross movement of a floor charging machine and thus avoid the time taken by the slewing movement required by the overhead type of charger.

Quite an appreciable saving in time can be obtained in this way and a time study recently carried out on all the operations involved has shown that to charge one box and return it to its starting point requires less than half the time with a floor type than with the overhead type of machine. Since in future large furnaces will be an economic necessity it is certain that separate marshalling bays should be embodied in all designs of new melting shops for quantity production.

CHARGING TIME AND PRODUCTION RATE

After the furnace has been charged with cold materials the heat input is increased to its maximum and thereafter the melting of the charge proceeds according to the characteristics of the furnace and the skill of the operator. It is general experience that the length of time required to work the charge is dominated by the time taken to charge the furnace and in order to obtain information on this matter an average was taken of many charges in one shop grouped under their charging times. When the time from charge to tap was plotted against the charging time it was found that a reasonably straight line was obtained, as shown in Fig. 6.† This line is given by :

$$\text{Time of charge} = 3{\cdot}0 + 1{\cdot}45 \text{ (charging time)}$$

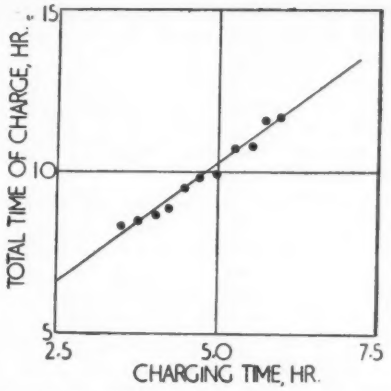


Fig. 6—Variation of charging time with total time from charge to tap

and it demonstrates that for each extra hour taken to charge the furnace the duration of the charge is prolonged by 1·45 hr. The furnace capacity was 88 tons in this case so that the production rate per hour was $88/(3{\cdot}0 + 1{\cdot}45t_c)$, t_c being the charging time. With $t_c = 2{\cdot}0$ the production rate would be almost 15 tons/hr., and I do not think that this is an impossible figure for a furnace of this size. It is certainly about 40% in advance of anything so far obtained, but with proper organization of the raw-materials assembly and adequate charging machines and boxes, it is capable of attainment. In electric-furnace operation, for instance, the advantages of quick charging have led to the development of basket charging, which has shortened the operating time appreciably.

The weight which a charging box will hold depends on its cubic capacity, and relating the charging time to the capability of the furnace to deal effectively with the weight of the cold materials involved necessarily implies also that the cubic capacity of the charging box bears some relation to these factors. The most important of these in this particular respect is the hearth area which controls the amount of heat received by the charge. The cubic capacity of the charging box should consequently vary with the hearth area and like it, therefore, should be proportional to the square root of W, the charge weight. An approximate rule which seems to be adequate is :

$$\text{Cubic capacity of box} = 3\sqrt{W}$$

While it is not suggested that such a relation should be an exact one it may prove a useful guide in the formulation of a basis for design which is self-consistent.

It is interesting to record that the first charging machine designed by Wellman for a 40-ton furnace used a box 6 ft. × 24 in. × 18 in. with a capacity of 18 cu. ft.—not very different from many of the boxes still used in Britain today. Admittedly larger boxes require larger doors with larger arches, and large arches are the cause of endless trouble. But it is not easy to understand a certain reluctance in this

* This crane was designed by Mr. T. W. Hand and constructed by Messrs. Russell & Co. (Motherwell).

† I am indebted to Mr. J. Gibson of Glengarnock for these results, each point being the average of about 25 charges in each class.

country to adopt the water-cooled arch which gets rid of this trouble and opens the way to a great many other operating advantages at a relatively slight increase in maintenance and supervision. Its use is certainly essential if larger charging boxes are to be used and the improvement in the output of greater capacity furnaces relatively cannot be achieved without them.

Boxes proportioned in this way will allow an adequate charging rate to be realized, a proper figure for which in future should not be less than 40–50% of the capacity per hour. It may be thought that this figure is somewhat high and that no existing furnaces are able to take their charge so quickly. But to be given the equipment and machinery capable of such a performance encourages the desire to take advantage of it and few furnace operators could resist temptations of that kind if placed in their way.

HEAT INPUT

There are two distinct stages in the course of a cold-metal charge during which the transfer of heat to the charge is controlled by very different conditions.

In the charging and melting periods the furnace is in process of filling or is filled with cold material and the charge can absorb a large proportion of its heat requirements by direct radiation and conduction from the flame, since the opening of the doors and the cooling effect of the charge on the walls reduces their temperature and consequently their contribution to the radiation energy of the furnace chamber.

Melting is therefore greatly facilitated by a hot intense flame directed down and through the charge. At this stage the efficiency of heat transmission depends on the degree of turbulence created in the burning gases. Since it is turbulence which controls the rate of combustion, what is desired is the maximum difference between the entering velocities of the gas and air so that the furnace-end design should attain as near as practicable the ideal of a jet of gas projected into still air which entirely surrounds it. We have by no means reached the limit of possibility in this respect, the most successful attempt to achieve the best conditions being probably the Venturi design at the present time. In this type of furnace differences of 100–150 ft. per sec. between the gas and air velocities are reached but there are other furnaces in operation today where this vital factor has not been fully appreciated and which work with a velocity difference of only 30–40% of this figure.

For intense combustion furnaces fired by compressed coke-oven-gas burners have marked possibilities in regard to future development in the industry.

When melting is complete and the charge is level new conditions arise where heat transfer by direct radiation from the flame is secondary to radiation from the hot walls of the furnace chamber.

The bath of liquid steel covered with slag is absorbing heat because of the chemical reactions and conduction through the hearth and so is at a lower temperature than the furnace walls and roof. It is receiving more heat by radiation than it gives out and this difference is supplied by heat from the flame.

Expressed as a percentage of the total radiated energy this difference can be stated with sufficient accuracy in terms of the absolute temperature T_1 of the walls and T_0 the temperature of the bath as:

$$D = 100\left(\frac{T_1}{T_0}\right)^4 - 1$$

The bath temperature is usually about 1600° C. and this expression shows how rapidly D increases with the value of (T_1-T_0). The limit of the wall and roof temperature with silica bricks can be taken as 1650° C. and in those circumstances the percentage of the total heat received by the bath which the flame must supply to maintain steady conditions is 11·1%.

This is exactly in line with the experimental results given in that very valuable report on "*The Influence of Port Design on Open-Hearth Furnace Flames*,"* where the measured difference between the downward and upward radiation was approximately from 8 to 15%.

If the use of basic bricks would enable the furnace walls and roofs to be run at 100° C. higher in temperature, the rate of heat input into the bath from the flame could be raised to 36% instead of 11% and this would obviously benefit the rate of working greatly. Such developments it is well known are already in active progress.

CHEMICAL REACTIONS

Within the past twenty years great progress has been made in our understanding of the physical chemistry of steelmaking processes and the work of investigators in this country and abroad has now enabled a tolerably clear picture to be formed of the nature of the chemical reactions which take place and of the limitations in our control over them. It is much too large a field to be reviewed even briefly, and I shall only touch on certain aspects in connection with present and future rates of steel production.

The refining of steel in the open-hearth furnace is fundamentally a slag–metal interaction, controlled by the composition and temperature of the two phases and the extent of their surface of contact. The rôle played by the furnace atmosphere, while not without importance, must be regarded as secondary to that played by the slag. During the finishing stage good steelmaking requires that slag composition must approximate to equilibrium conditions and this restricts within certain limits possible variations in slag composition.

It seems unlikely therefore that any great improvement in production rate can be expected from mere changes in slag composition. On the other hand the dependence of reaction rates on diffusion across the slag–metal interface makes them sensitive to changes in the extent of that surface. The extreme rapidity of the chemical reactions in the Bessemer converter is very greatly assisted by the intense agitation and the large surface of contact thus created between the metal and the slag. But while this principle is clearly understood it cannot be said that attempts to make use of it in open-hearth practice have met as yet with any success. It is a line of advance that still awaits the right inventor.

**The Iron and Steel Institute*, 1946, *Special Report No.* 37.

The effect of temperature is also important and it has been broadly said that chemical changes double their rate of reaction for every rise of 20° C. in the temperature at which they take place. The provision of better refractories with a substantially higher softening temperature would enable furnace reactions to be speeded up appreciably, and in particular carbon removal which absorbs heat could be quickened by the greater heat flow into the bath from the furnace walls and roof.

The absorption of heat when carbon is oxidized by FeO is avoided when direct oxidation is carried out and the prospect of doing this has been greatly strengthened by recent work on the use of oxygen in open-hearth furnaces, particularly in America. It has been shown there that oxygen can be used to increase the intensity of flame combustion by enrichment of the air, to melt scrap by jet impingement or to oxidize directly the carbon in the bath.

From the small part played by direct radiation it cannot readily be seen how the use of enriched air can contribute effectively to the heat balance or the production rate.

The melting of scrap by jet impingement will be more efficient but undoubtedly the most extensive use for oxygen will be found in direct oxidation. In this case the reaction generates heat which can be retained without punishing the furnace refractories and it can be an aid in keeping the reaction temperature at a high level.

Of the technical difficulties so far encountered, the splashing of slag on the furnace walls and roof, due to the rapid evolution of carbon monoxide, when oxygen is blown into a high-carbon bath gives rise to a pronounced increase in refractory consumption.

But the oxygen is a great help in shortening the time required to reduce the carbon to low percentages, *i.e.*, 0·04–0·08, although its efficiency as an oxidizing agent falls off rapidly at these lower contents. Low carbon in the bath requires a high-oxide slag and with lowering carbon the FeO in the slag increases and moves towards its equilibrium concentration. But this can only take place if the FeO required by the slag is supplied by the direct combination of the iron and the oxygen. So the lower the carbon the greater the proportion of oxygen used for this purpose and the greater the loss in oxidation efficiency from the steelmaking angle.

Such problems, however, need cause no disquiet. The use of oxygen is as yet in its infancy and there can be no question that its influence on future steelmaking practice will be profound. Already in America five casts per 24 hr. have been attained from a 150-ton furnace with heat consumptions of 2·5 million B.Th.U./ton, and although these are exceptional results not always capable of repetition they point the way to new standards of production.

The use of oxygen holds out prospects for the rapid production of steel which we can apprehend but which at the present time we are wholly unable to assess. It will demand an expansion in the means to produce oxygen which we must regard as the initial steps taken towards the creation of an entirely new technical industry.

INGOT SIZE IN RELATION TO OUTPUT

With high-production furnaces tapping at regular intervals the problem of casting and handling the ingots produced in the casting pit requires careful organization. As the size of the shop increases a stage is reached when separation of functions and operations becomes a necessity. It is no longer possible to cast, strip and load in a single shop and the casting bay must be reserved for casting only, leaving stripping and loading to be handled in a shop designed for this purpose.

Car casting with a separate stripping bay is so far the only solution, but even then the ingot size must be related to the furnace capacity to synchronize the operating time. Between 15 and 20 ingots per cast seems to be the ideal ratio although it must be admitted that the ideal ratio is not always possible of attainment in practice.

Fortunately, with ladles designed on a basis of similarity, keeping the ratio of ladle diameter to nozzle diameter constant, the time required to cast the whole charge varies but little, since it is proportional to $W^{\frac{1}{6}}$ where W is the weight of the charge. Doubling this weight will increase the time required to empty the ladle by only about 11% and the time to fill a mould proportional to the weight of the charge will increase by the same percentage. The tendency for ingot cracks to occur is thus lessened with larger capacity furnaces.

HEAT RECOVERY

The first waste-heat boiler in an open-hearth furnace was installed by McKenzie at Motherwell in 1898. This boiler was an ordinary Lancashire type and it interfered so much with the furnace draught that it had to be removed. Not until an induced-draught fan was added to a Babcock type boiler 14 years years later was success achieved and 4500–5000 lb. of steam per hour obtained from a 45-ton furnace. With the ever-increasing cost of fuel the need for recovering waste heat today is greater than ever.

Even in a well designed furnace, to attain a high production rate inevitably entails some extravagance in the use of fuel since quick melting cannot be obtained without some sacrifice of efficiency in heat transfer. With a waste-heat boiler the excess heat can be recovered as steam while the use of the exhaust fan gives more control over the furnace draught and a wider range of draughting conditions.

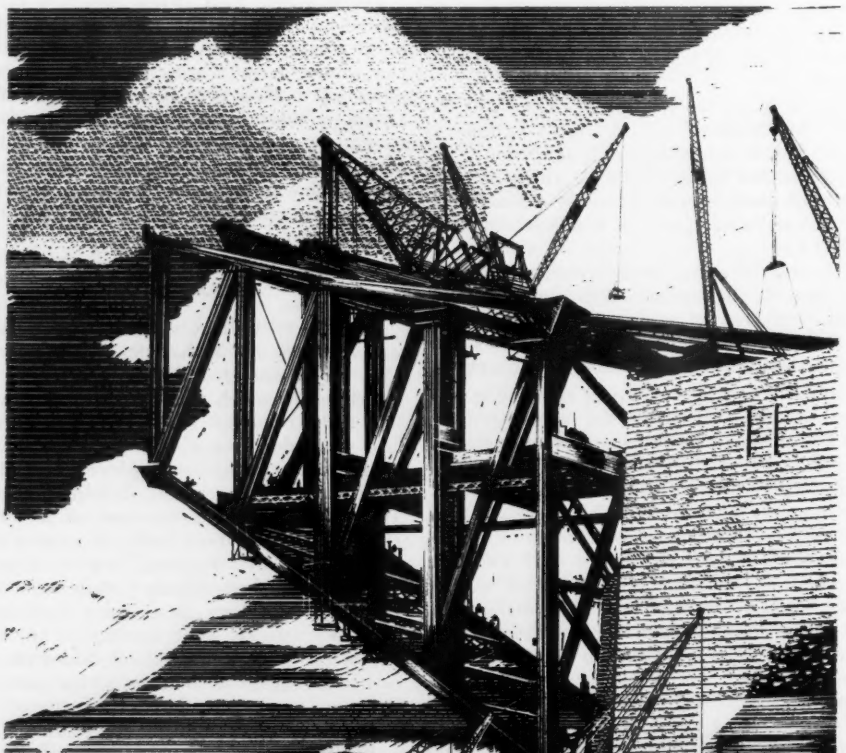
For the greatest heat recovery all flues should be encased in steel and heat-insulated, and experience has shown that the cost of doing this is well justified. The flue gases are generally at a temperature of 550–650° C., and after passing through the boiler leave at about 250° C., so that the temperature extraction efficiency is about 60%. There are great difficulties no doubt, in the recovery of the remainder, but the cost of fuel justifies the most serious attempts being made to get this remaining heat back into the works economy. In his original scheme McKenzie used economizers for this purpose, but this was not altogether a success and was abandoned. The great obstacle is, of course, the presence of SO_2 in the flue

gases and the corrosive effects whenever the temperature falls below the condensation range.

At present, with efficient fire-tube-type boilers, 14,000–15,000 lb. of steam per hour at 200-lb. pressure are being recovered regularly from 90-ton open-hearth furnaces. During the war, when large quantities of oily steel turnings were used as scrap, the steam recovered during the charging period sometimes reached astonishingly high figures owing to the heat recovered from the burning oil.

Waste-heat recovery is also applicable to soaking pits and in order to reduce the capital cost involved a scheme has been worked out for discharging the waste gases from two soaking pits independently through each half of a single boiler. This has worked well and approximately 3000 lb. of steam per hour are being recovered from the heating of 2200–2600 tons of ingots per week. While all schemes have not yet been completed the total coal saving due to waste-heat recovery within the works of the Colville Group already amounts to almost 100,000 tons each year.

Heat is not the only waste product in our industry which will repay study and attention, and I will conclude by saying that it is only a determination to find some use for all the products which have hitherto been regarded as waste as well as by a correct understanding of all the factors concerned in intensive production that we can hope to maintain the economic success of the steel industry in these unbalanced and difficult times.



IRON AND STEEL
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PLANT DESIGN · MANUFACTURE · RESEARCH · DEVELOPMENT

The Annealing of Cast Iron in Hydrogen

By J. Bernstein, A.R.I.C., A.C.T.C.(Birm.), A.I.M.

SYNOPSIS

The decarburization of cast iron in hydrogen atmospheres is discussed, and experiments in which white cast irons were annealed in carefully dried hydrogen are described and the resulting structures illustrated. It was found when annealing at temperatures between 850° and 1050° C. that some slight decarburization occurred and was accompanied, for annealing times of up to about 100 hr., by the deposition near the surface of a layer of graphite ; prolonged annealing eventually removed this graphitic layer. Dry hydrogen was found to have a marked stabilizing influence upon the carbide in white irons. The annealing of grey irons in carefully dried hydrogen was also investigated, and nodular graphitic structures were observed near the edge as a result of this treatment. The decarburization of white cast irons in moist hydrogen is shown to be similar to that obtained by annealing white cast irons in atmospheres containing carbon dioxide. The annealing of grey cast iron in moist hydrogen appears to be a complex process.

Introduction

THE decarburization of white cast iron by means of gaseous mixtures has recently achieved considerable industrial importance[1, 2, 3, 4, 5] and it would seem that the process is likely to become firmly established for the commercial production of white-heart malleable cast iron. In this gaseous decarburization process the white-iron castings are annealed at elevated temperature in an atmosphere containing carbon dioxide. This gas causes the decarburization of the white cast iron by a surface reaction at the edges of the castings, according to the following equation :

$$\text{Carbon (in iron)} + CO_2 = 2CO.$$

Carbon from the centre of the sections then diffuses to the surface and complete or partial decarburization can eventually be obtained, according to the length and temperature of the annealing treatment.

It is well known that atmospheres containing water vapour are also effective decarburizing agents, and again a surface reaction occurs, accompanied by diffusion of carbon. Decarburization can be effected, however, by hydrogen, and it has been fairly well established that the rate of decarburization in hydrogen atmospheres varies with the water content of the atmosphere.[6]

Austin,[7] in a study of the decarburization of steel in hydrogen atmospheres, has pointed out that when special precautions are taken to dry the hydrogen the decarburization effect still exists, but is very limited. Baukloh and Knapp[8] have also studied the decarburizing effect of hydrogen, and to explain some of the structures produced have suggested that hydrogen may actually penetrate the steel or cast iron during the decarburizing process. No satisfactory explanation of how this could occur was put forward. In view of the findings of Austin and of Baukloh and Knapp it is obvious that some considerable interest attaches to the influence of annealing white and grey cast iron in carefully dried hydrogen atmospheres. In the course of a general investigation of gaseous decarburization the present author carried out a number of experiments with dry hydrogen and obtained results which differed in some respects from those of previous workers, and this paper is a record of these experiments and the results obtained. The structures which were produced indicated that decarburization in dried hydrogen is probably more complex than has hitherto been suspected, but no detailed explanation of the results observed will be attempted at this stage. In view of the importance of the purity of the gaseous atmosphere upon annealing in hydrogen, a detailed account will be given of the method of purifying the gas and the experimental technique used.

EXPERIMENTAL PROCEDURE

The apparatus used for the purification of commercial hydrogen is illustrated diagrammatically in Fig. 1. Hydrogen from a cylinder was passed over platinized asbestos (*C*) maintained at 1000° C. and

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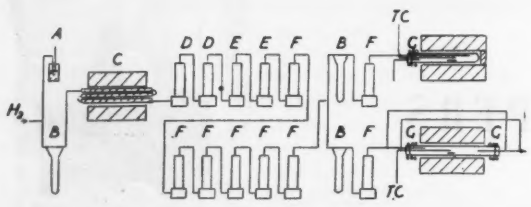

A	Mercury valve	*E*	Soda asbestos
B	Flow gauges	*F*	Phosphorus pentoxide
C	Platinized asbestos	*G*	Water-cooled copper coils
D	Calcium chloride	*TC*	Thermocouple

Fig. 1—Arrangement of the annealing furnaces and apparatus for purifying and drying commercial hydrogen

contained in three alumina tubes each 30 in. long × 1 in. in dia., connected in series. The gas was then passed through two towers 16 in. high, packed with finely granulated (10–14-mesh) anhydrous calcium chloride (*D*), two towers packed with anhydrous soda asbestos (*E*) (also 10–14-mesh), and then through six towers of the same size filled with anhydrous phosphorus pentoxide (*F*). The gas was then divided into two portions, the rate of flow in each being regulated with two stop-cocks and flow gauges (*B*) calibrated for hydrogen. As the confining liquid in the flow gauges was an aqueous solution, additional towers containing phosphorus pentoxide were placed between the flow gauges and the furnaces.

One portion of the gas entered a silica furnace tube fitted with an arrangement for reversing the direction of flow of the gas through the furnace, and the other portion was passed through a slightly shorter silica furnace tube sealed at one end. The inlet tube for the hydrogen extended in this case beyond the specimen under test, to ensure that the gas passed over the specimen.

The furnaces were closed with rubber bungs protected by silica baffles and were sealed with wax. The ends of the furnaces were water cooled (*G*) to prevent the wax from melting and to prevent overheating of the rubber bungs. The outlet tubes of the furnaces conveyed the exit gases along lengths of rubber tubing at the end of which the gases escaped into the atmosphere through glass jets of fine bore.

The phosphorus pentoxide drying towers were packed as shown in Fig. 2. Glass wool, well dusted with phosphorus pentoxide, was included to increase the surface area of absorbent in contact with flowing gas. After completion of each experiment the reagents were renewed.

With this apparatus it was hoped to remove oxygen, carbon dioxide, and water vapour present as impurities in the hydrogen, but no analytical determinations for the purity of the hydrogen were made.

The furnace temperatures were controlled to within ± 2° C., and chromel–alumel thermocouples (*TC*) covered with silica sheaths were used. The thermocouples were renewed after each test above 850° C.

After sealing the furnace tubes containing the specimens under test the apparatus was tested for leaks and then the furnace containing the platinized asbestos was switched on. Hydrogen was allowed to flow through the apparatus to remove air from the

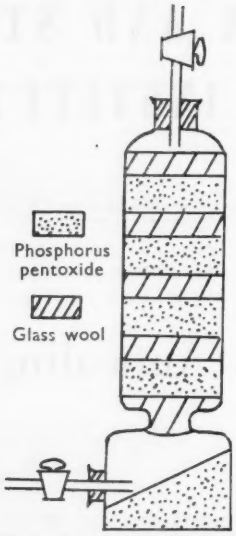

Fig. 2—Method of filling the drying towers

drying towers and the furnace tubes. After 6 hr. the furnaces containing the specimens were heated to between 200° and 250° C. and left overnight with hydrogen flowing through at a rate of about 50–100 c.c./min. The water in the copper cooling coils was not turned on, in order that the bungs would become warm and any water vapour would be removed from the furnace tubes without being condensed in the exit tubes passing through the bungs. This purging operation occupied 24 hr., after which time the current input to the furnaces was increased so that the required annealing temperature was attained in 6 hr. During this period the cooling water was turned on and the rate of flow of hydrogen was adjusted to the desired value. The mercury blow-off valve (*A*) was set so that an excessive rate of flow would be avoided if the hydrogen pressure changed abruptly.

The closed-end furnace tube was 30 in. long, 2¼ in. in internal diameter, and 2½ in. in external diameter. The other furnace tube was 36 in. long and of the same internal and external diameters as the closed-end tube. The specimens used in this investigation were all machined cylinders 2 in. long and 0·625 in. in dia. When all the conditions were the same the results obtained using the closed-end furnace were identical with those obtained using the other furnace.

ANNEALING WHITE CAST IRON IN FLOWING DRY HYDROGEN

For the experiments upon the annealing of white cast iron in flowing dry hydrogen, a white iron of the following composition was used:

Total carbon	3·12%
Silicon	0·55%
Manganese	0·34%
Sulphur	0·235%
Phosphorus	0·064%

In the first instance samples of this white iron were annealed for 100 hr. at each of the following temperatures: 750°, 850°, 900°, 950°, and 1000° C.,

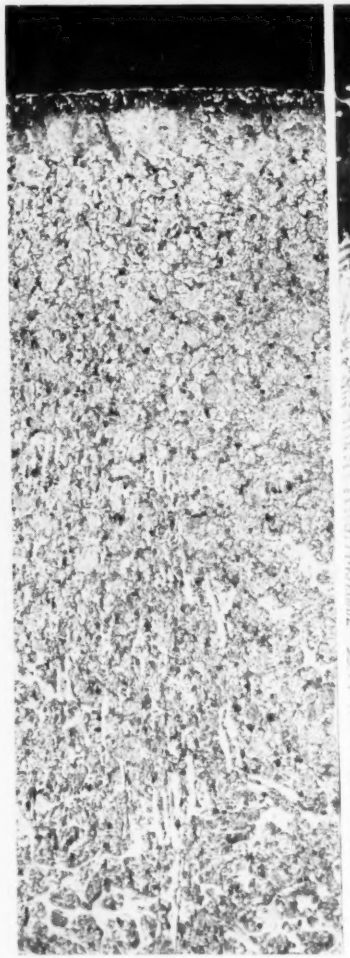

Fig. 3—Structure of white-iron specimen annealed for 100 hr. at 850° C. in pure dry hydrogen × 60

Fig. 4—Graphite layer at edge of specimen illustrated in Fig. 3 × 600

Fig. 5—Structure of white-iron specimen annealed for 50 hr. at 1050° C. in pure dry hydrogen × 60

Fig. 6—Graphite layer at edge of specimen illustrated in Fig. 5. Unetched × 600

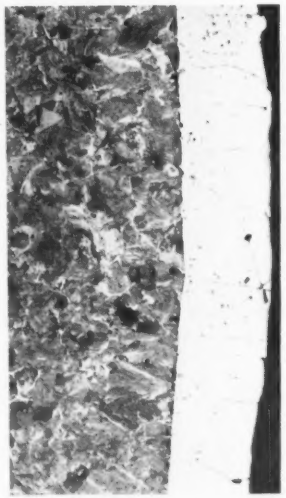

Fig. 7—Structure of white-iron specimen annealed for 275 hr. at 1000° C. in pure dry hydrogen × 60

Fig. 8—Continuous band of cementite at edge of specimen annealed for 100 hr. at 950° C. in stationary dry hydrogen atmosphere × 600

(Figs. 3 to 5, 7, and 8 etched with 4% picric acid)

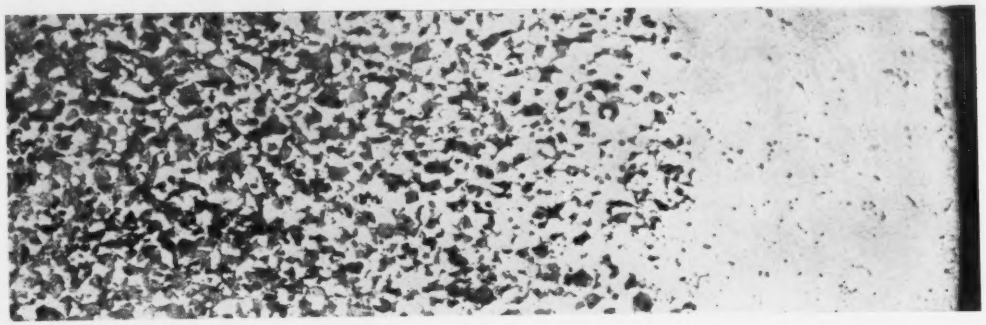

Fig. 9—Structure of white-iron specimen annealed for 100 hr. at 1000° C. in a hydrogen/water-vapour atmosphere × 60

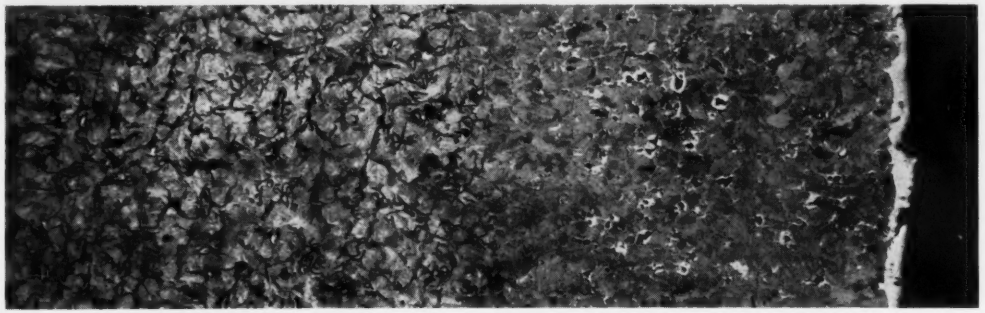

Fig. 10—Structure of grey-iron specimen annealed for 100 hr. at 1000° C. in pure dry hydrogen × 60

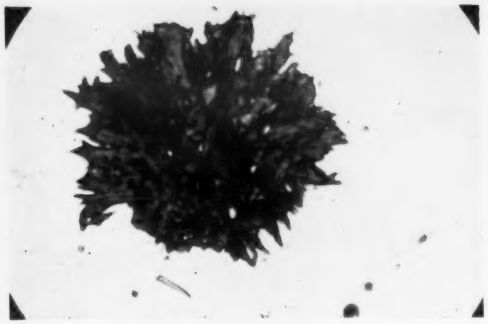

Fig. 11—Type of nodular graphite observed in the grey-iron specimen illustrated in Fig. 10. Unetched × 600

Fig. 12—Another form of graphite observed in the grey-iron specimen illustrated in Fig. 10. Unetched × 600

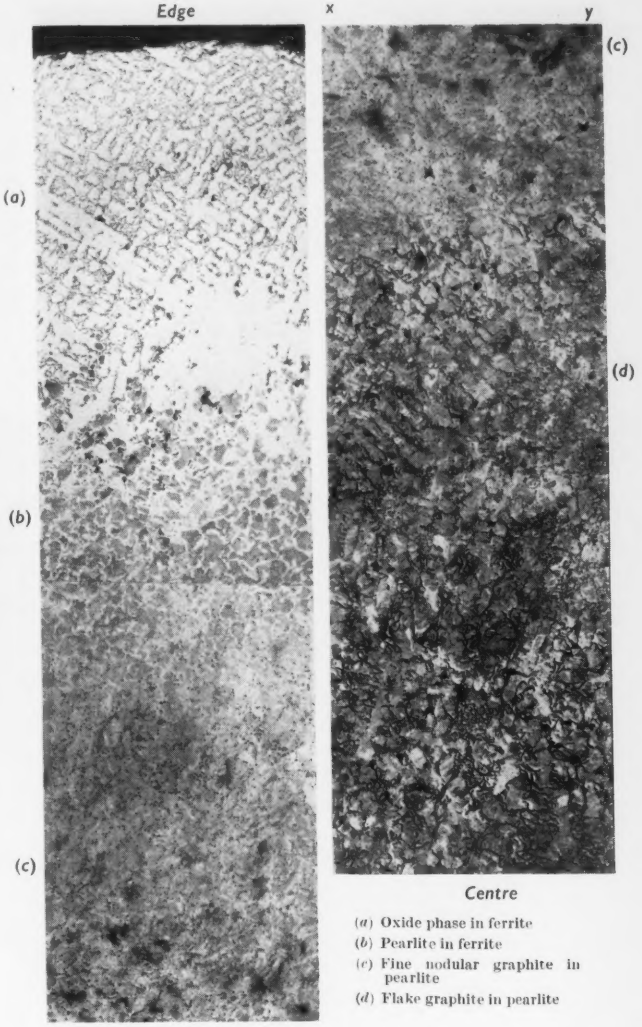

Fig. 13—Structure of grey-iron specimen annealed for 100 hr. at 1000° C. in a hydrogen/water-vapour atmosphere. × 60. Micrograph cut at *x y* and reduced to two-thirds linear in reproduction

(Figs. 9, 10, and 13 etched with 4% picric acid)

at 1050° C. for 50 hr. The rate of flow of hydrogen was 200 c.c./min. in each case. After the completion of the 100-hr. treatment the heating current to the furnaces was switched off, the flow of hydrogen being continued until room temperature was reached. Cooling down to 700° C. took about 4 hr., but the flow of hydrogen was not stopped until 24 hr. after switching off the heating current. The specimens were weighed before and after treatment, and microspecimens were taken transversely at the centre in each case. The original white-iron structure persisted uniformly over the whole section of the specimen annealed at 750° C. No decarburization was apparent, but there was a slight reduction in weight of the specimen, and chemical analysis indicated that 0·04% of carbon had been removed.

The structures of the other specimens annealed at higher temperatures were all essentially of the same type, and so it is necessary to describe only one structure in detail. For this purpose it is convenient to consider the sample annealed at 850° C. The structure of this sample is shown at a low magnification in Fig. 3. At the outer edge there was a heavy but narrow concentration of graphite. Proceeding inwards, this was followed by a layer of fine pearlite and then by a deeper layer of coarser pearlite, together with hypereutectoid cementite, until the original white-iron structure occurred with massive eutectic cementite. The graphite at the periphery of the sample was associated with ferrite. The structure of this graphitic layer is shown more clearly at a higher magnification in Fig. 4. In this sample no graphitization of the eutectic carbide had occurred in the centre of the section.

The samples annealed at 900°, 950°, and 1000° C. all had very similar structures to that which has been described for the sample annealed at 850° C., except insofar as the amount of massive eutectic cementite remaining became smaller with increasing annealing temperature. Each of these samples had the graphitic rim and in no case had graphitization occurred in the centre of the sections.

The sample annealed at 1050° C. also had a graphitic rim, but graphitization of the eutectic carbide had occurred in the centre of the section. These two features are illustrated at a low magnification in Fig. 5. In this case the graphitic rim was particularly well developed and was clearly separated from the surface of the sample by a thin layer of metal. The actual graphitic layer was almost continuous and pointing into the centre of the sample, but attached to this graphite layer were a number of apparently normal graphite flakes. This structure is illustrated at high magnification in Fig. 6.

Some of these samples were analysed for sulphur and carbon after treatment and it was found that some decarburization and desulphurization had occurred, the extent of this increasing with increasing temperature. The figures obtained for decarburization and desulphurization after annealing for 100 hr. were as follows:

Annealing Temperature, °C.	Carbon Removed, %	Sulphur Removed, %
850	0·20	0·010
900	0·28	0·013
1000	0·40	0·017

The decarburizing effect of dry hydrogen is clear from these figures, but it is obviously not a very rapid process. The occurrence of the graphite rim near the edges of these samples is a unique finding which has not been reported previously. It would appear that there has been, by some means as yet unknown, a transport of carbon from the centre of the section to the edge, with the deposition of graphite at this position. The stabilizing influence of hydrogen upon the eutectic carbide is clear from the fact that even after 100 hr. at 1000° C. no graphitization had occurred. Samples of this same iron, annealed in pure nitrogen atmospheres, were found to be completely graphitized after annealing for 34 hr. at 950° C., graphitization beginning after 3 hours' annealing at this temperature.

The annealing times of the samples which have been described so far in this paper have not exceeded 100 hr., and some interest attaches to the effect of prolonged treatment under these conditions. It might be expected that the graphitic layer would increase in depth and that the degree of general decarburization would increase. Several experiments involving longer annealing times were carried out, all leading to the same general result. For example, the specimen of the white iron annealed for 275 hr. at 1000° C. gave the structure illustrated in Fig. 7. This micrograph shows the extreme edge of the sample, and an outer band of columnar ferrite can be seen with a sharp line of demarcation separating it from an area of fine pearlite. No peripheral layer of graphite existed in this sample, although some graphitization of the eutectic carbide had occurred towards the centre of the section.

It would appear from this and similar experiments that the graphitic layer which forms by annealing for relatively short times (*e.g.*, 100 hr. at 1000° C.) is gradually removed when the annealing is prolonged (*e.g.*, 275 hr. at 1000° C.). Various cases were obtained where the graphitic layer had been partially removed. The time required to remove the graphitic layer would appear to depend upon the temperature of the annealing. A sample annealed at 1050° C. showed some removal of the graphitic layer after only 100 hours' annealing.

Cylindrical specimens having a small hole drilled along the axis were also annealed in dry hydrogen and it was found that the graphitic layer developed under the same conditions both on the outer surface and the inner surface.

ANNEALING IN STATIONARY DRY HYDROGEN ATMOSPHERES

Using the apparatus which has been described earlier, it was found that by reducing the rates of flow of the hydrogen below 100 c.c./min. the extent of decarburization was reduced and the formation of the graphitic layer tended to be inhibited, and it was necessary to maintain rates of 200 c.c./min. for reproducible results. With rates of flow in excess of this value, consistent and similar results were obtained.

In view of the above observations it was decided to investigate the influence of annealing in a stationary hydrogen atmosphere. For this purpose the furnace was flushed with hydrogen before heating in a manner similar to that described previously, but when the

heating was begun the exit from the furnace was sealed and the input of hydrogen adjusted to give a slight positive pressure inside the furnace. Under these conditions a sample of white iron was annealed for 100 hr. at 950° C.

This sample showed no measurable decarburization and the general microstructure was very similar to that of the as-cast material. At the surface of the specimen a continuous narrow band of cementite was present, and this is shown at a high magnification in Fig. 8.

RATE OF DECARBURIZATION IN FLOWING DRY HYDROGEN ATMOSPHERES

The experiments described so far have indicated that dry hydrogen has a slight decarburizing effect at elevated temperatures on white cast iron, and also that a graphitic layer is formed. It was thought that a study of the change in rate of decarburization with time at a given temperature might throw some light upon the mechanism of decarburization and the formation of the graphitic layer. Generally, when the decarburizing reaction occurs at the surface of the sample and is controlled by the rate of diffusion of carbon from the centre of the section to the edge, the rate of decarburization begins with a relatively high value and then gradually decreases, the rate of decrease being governed by the increasing distance over which the carbon must diffuse to reach the edge of the sample. It is well known that this state of affairs exists when annealing in moist hydrogen and in carbon-dioxide/carbon-monoxide atmospheres.[6, 9] If decarburization in dry hydrogen is a similar process, a similar type of rate-of-carbon-removal curve should be obtained.

To investigate this aspect of the problem experiments were carried out by annealing white-iron samples in dry hydrogen atmospheres, the specimens being suspended in the furnace from one arm of a chemical balance supported on a stand vertically above an annealing furnace the tube of which was placed in the vertical position. Similar apparatus has been described in the literature.[9, 10] The precautions previously adopted for removing air and water vapour from the furnaces were observed in these experiments.

The suspended specimens were weighed every ½ hr. for the first few hours, and then every hour for the next 50–60 hr. After this time, readings of the balance were taken every 5 or 10 hr. until the completion of the test. Each determination was repeated and the residual carbon content of the iron was calculated from the total loss in weight of the specimens, the resulting figure being compared with that obtained by chemical analysis. The figures agreed very well, when due allowance was made for the desulphurizing effect. As the loss in weight due to desulphurization was only very slight in each case, the consequent error on the reported results is very small.

Tests of this type were carried out at 1000° and 900° C., and for comparison purposes a similar experiment was carried out at 1000° C. with moist hydrogen containing approximately 2% of water vapour. These experiments again confirmed that pure dried hydrogen has a limited decarburizing effect which increases with increasing temperature. The rate of decarburization,

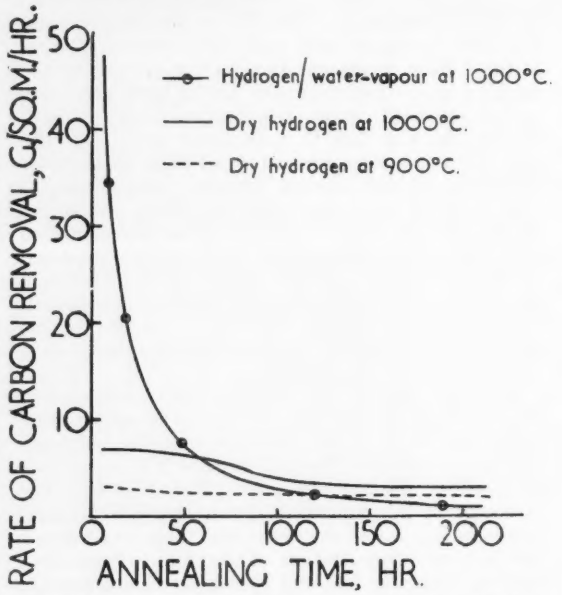

Fig. 14—Rate of decarburization of white iron in dry hydrogen and in hydrogen/water-vapour atmospheres

expressed in terms of grammes per square metre of surface of the sample per hour has been plotted against the time of annealing, and the resulting curves are shown in Fig. 14. The curve for moist hydrogen is typical of that obtained where decarburization is effected by a surface reaction the rate of which is controlled by a diffusion process. The curves obtained for annealing in dried hydrogen show that decarburization under these conditions is an extremely slow process which tends to become slower with increasing time. It is not possible to infer from these curves whether the diffusion of carbon is a controlling process or whether the rate of decarburization is influenced at all by a chemical surface reaction between hydrogen and carbon. The present investigator is unable to offer any explanation for the discontinuity apparent in the curve for the sample annealed in dry hydrogen at 1000° C. Samples annealed in moist hydrogen under these conditions gave microstructures normal for decarburization occurring by a surface reaction. A typical example is illustrated in Fig. 9, which shows the surface structure of a sample of white iron annealed in moist hydrogen containing approximately 2% (by volume) of water vapour after annealing for 100 hr. at 1000° C.

ANNEALING OF GREY CAST IRON IN DRY HYDROGEN

Since at a certain stage in the annealing of a white cast iron in dry hydrogen it is possible to obtain a graphitic layer, it would seem that this condition, when achieved, bears some resemblance to the annealing of a grey cast iron under similar conditions. It was therefore considered to be of interest to determine the influence of annealing a grey cast iron in a dry hydrogen atmosphere.

For this purpose an iron of the following composition was chosen :

Total carbon	3·27%
Silicon	1·82%
Manganese	0·93%
Sulphur	0·038%
Phosphorus	0·032%

Several experiments were carried out with this iron and similar results were obtained in each case. The structure of a specimen annealed for 100 hr. in dry hydrogen at 1000° C. is shown in Fig. 10 and may be taken as typical of the results obtained at all temperatures between 800° and 1050° C. Some decarburization occurred at the surface, and in the adjacent zone the flake graphite structure had been replaced by very fine nodular graphite. The centre of the section had the normal flake graphite structure. The extreme outer edge of the sample consisted of a thin band of ferrite with no graphite. A typical example of the nodular graphite obtained in the region adjacent to this ferritic band is shown at a high magnification in Fig. 11. In some areas these nodules appeared to consist of remnants of graphite flakes upon which a further precipitation of graphite had taken place during the anneal. A typical example of this is illustrated in Fig. 12. Chemical analysis confirmed that little decarburization had taken place.

ANNEALING OF GREY CAST IRON IN MOIST HYDROGEN

When grey cast irons of the same analysis as given previously were annealed in moist hydrogen some decarburization was obtained, but the structures were complex. A typical example is illustrated in the composite micrograph shown in Fig. 13. This is taken from a sample annealed for 100 hr. at 1000° C. The outer zone consisted of ferrite with an oxide phase replacing the original pattern of graphite. This was followed by a zone containing a mixture of ferrite and pearlite in increasing amount, and then by a relatively deep zone containing fine graphite nodules in a matrix of pearlite. Following this the normal grey-iron structure was obtained.

DISCUSSION OF RESULTS

The experiments reported above show that the decarburization of white iron by pure dried hydrogen is more complex than has hitherto been thought. At temperatures of 850° C. and above it appears that the slight decarburization is at first accompanied by the removal of carbon from the inner regions of the sample and its deposition as graphite just below the surface of the specimen. It has been frequently assumed in the literature that decarburization with hydrogen occurs according to the reversible reaction $Fe_3C + 2H_2 \rightleftharpoons 3Fe + CH_4$. It is not known whether this reaction occurs only at the surface of the specimen. There is, however, some evidence that hydrogen can penetrate ferrous alloys, and the fact that during the annealing of a white cast iron the carbide phase is stabilized at elevated temperatures confirms that this inward penetration of hydrogen has occurred. Whilst it is possible to imagine the diffusion of hydrogen through the white cast iron, it is less easy to imagine, as has been suggested by Baukloh and Knapp,[8] the reaction of hydrogen with carbon in the interior of a sample, with the formation of methane which then could diffuse out of the sample simultaneously with the inward penetration of hydrogen. This possibility is unlikely because of the relatively large size of the methane molecule. However, the evidence which has been presented in this paper does indicate that a process of this type may occur. It is, of course, possible that a hydrocarbon other than methane and of smaller molecular size is formed, and that this could diffuse to the outer surface. The reasons for this outward diffusion are not immediately apparent and if such a process occurred it would appear that near the surface of the sample the compound becomes unstable, giving a deposition of graphite. The fact that the graphite may be completely removed by prolonged annealing would suggest that with the progress of decarburization the supply of carbon to the graphitic layer becomes limited and that a reaction occurs, either directly or indirectly, between the hydrogen atmosphere and the graphitic layer, resulting in its final elimination. That a process of this type can occur to some extent is also demonstrated by the effect of annealing a grey cast iron in a dry hydrogen atmosphere, when some elimination of the graphitic carbon results. It is, of course, possible that, simultaneous with an inward penetration of hydrogen, a normal surface reaction occurs between the hydrogen atmosphere and the carbon at the surface of the sample which, by reducing the carbon content of the surface, would provide the carbon-concentration gradient necessary for the outward movement of carbon.

It is felt that the evidence available is insufficient to permit theorizing beyond this point. Quite obviously decarburization with hydrogen is a complex process, and much further work requires to be carried out before a satisfactory explanation can be achieved.

Acknowledgments

The author wishes to thank the Council and Director of the British Cast Iron Research Association for permission to publish these results.

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Bristol in 1576

THE WIRE-DRAWERS OF BRISTOL

1312–1797

By DR. H. R. SCHUBERT

IT is well known that, apart from London, York[1] and Coventry[2] were centres of the wire industry in medieval England. In this respect Bristol is hardly recognized, yet wire-drawing at Bristol can be traced back to the beginning of the fourteenth century. In a roll of taxes levied in the town for King Edward II, dated 16th December 1312, a certain "Robertus le Wirdrawere," living in the St. Mary-le-Port quarter, is assessed at 10*s*. for his movable goods.[3]

Evidence of a proper guild or Company of wire-drawers and wool-card-makers is furnished by regulations concerning the "guild drinkings" at Bristol, dated 20th May, 1450.[4] It was ordained by "the Mayor, Sheriff and all notable persons assembled in the Council House of the Town of Bristol" that the craft guilds of the town should receive certain quantities of wine at the guild drinkings, which took place at the midsummer watch festivities on the eves of St. John and St. Peter, provided that they sent their own servants and pots to fetch the wine dispensed. From the quantities allotted, inferences may be drawn as to the sizes of these craft guilds. The two largest were evidently the guilds of the Weavers and the Tuckers, each receiving 10 gal. This is quite in accordance with the status of these crafts in the economic life of the town in the Middle Ages, when the manufacture of wool-cloth, based on the famous Cotswold wool, was the staple industry of Bristol and the product was exported all over the world. The "wiredrawers and cardmakers," with their wine allocation of 3 gal., belonged to the smaller crafts of the town.

In the reign of King Edward IV (1461–83) the position of the craft guilds in public and economic life was greatly strengthened. In 1463 the king enacted a statute prohibiting the importation of an immense variety of foreign manufactures. Amongst the many ferrous articles specified in the statute, pins, wool-cards, and white wire are mentioned.[5] White wire, referred to in the statute as "blanch iron thread commonly called and named White Wire," was iron wire, in contrast to "yellow wire" which signified brass wire.

The protectionist legislation of Edward IV was part of the king's policy for the encouragement of native industries. Another part of the same policy was the granting of charters to craft guilds, especially those of London.[6] In many other towns the crafts followed this example and obtained charters from their respective municipal authorities. At Bristol a charter was granted in 1469 (September 26th) to the "cardewyre drawers and cardemakers dwelling in the towne."[7]

Main objects of the regulations laid down in the charter were to ensure good work by the members of the guild and an adequate supply of competent workers by the training of young people. The charter directed that nobody within the "shire and precinct of Bristowe" shall "occupy neither cardewyre drawing nor carde makyng without that he or they be sufficiently learnyd in the seid craftes."

Admission to apprenticeship depended upon the applicant being free-born and not having been in conflict with the laws of the country, the apprenticeship being enforced for a period of seven years. At the

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[1] Victoria County History of Yorkshire, vol. 2, p. 333. London, 1912.

[2] Victoria County History of Warwickshire, vol. 2, p. 210. London, 1908.

[3] E. A. Fuller, "The Tallage of Edward II and the Bristol Rebellion," *Transactions of the Bristol and Gloucestershire Archaeological Society*, 1895, vol. 19, p. 262.

[4] E. W. W. Veale, "The Great Red Book of Bristol," Part I, p. 126. Bristol, 1933: Bristol Records Society's Publications, vol. IV.

[5] The Statutes of the Realm, vol. 2, p. 397. London, 1816.

[6] G. Unwin, "The Gilds and Companies of London" (third edition), p. 163. London, 1938.

[7] "The Great Red Book of Bristol Corporation," folios 211–212 (a manuscript now preserved in the Archives Department of the Council House at Bristol. Miss E. Reeper, Archivist of the City, very kindly facilitated the study of various manuscripts).

end of this time the apprentice could become a master either immediately or after a few years of working as journeyman under a master for wages. Sometimes journeymen were permitted to set up for themselves. Further, the guild protected its members against competition from outside, *i.e.*, cardwire-drawing and cardmaking within the city of Bristol and its precincts were exclusively restricted to members of the guild and their employees. Other craftsmen, especially those who were not burgesses, could set up only when working under a member of the guild.

The charter also directed that on the 21st September of each year, two " wardens " of the craft were to be elected, one being a cardwire-drawer and the other a cardmaker. The wardens so elected presided at the assemblies and possessed executive powers ; they also supervised the quality of the goods manufactured and were authorized to search for and to seize defective ware. At the end of their term of administration they rendered account of the monies received and spent. These accounts, together with the decisions reached at the assemblies of the masters (whose names are recorded for each year) and details of the fines imposed on members of the guild, form the contents of two manuscripts composing the minute-books of the guild and covering a period of three hundred years.[8] The numerous detailed items in these minute-books furnish a splendid means of investigating the life and activities of one of Bristol's craft guilds over the period mentioned.

The craft of wire-drawers and cardmakers, as it is called in 1497 and in the following years, absorbed one of the lesser crafts of Bristol, namely the " pinners," that is, the pinmakers, who were not numerous enough to form a craft guild of their own. The masters numbered between fourteen and twenty-three from the year 1497 until the end of the following century, and on the average only two were pinners. The highest number of pinners within the guild at any one time was six, in 1526. All the other masters were cardwire-drawers or card-board-makers. Occasionally one of the masters is referred to as a " hook-maker," *i.e.*, an artisan who manufactured fish-hooks. In addition, " smithers, brakemen and girdlemen " are mentioned in the minute-books, designations exactly similar to those used in Coventry records as early as 1435 and representing the professional terms for those engaged in the various stages of the wire-drawing process, from the preparatory work done by the smither, *i.e.*, the smith, to the drawing of cardwire ready for making wool-cards.[9]

In attempting to reconstruct the method of wire-drawing applied by the wire-drawers of Bristol, three main points have to be borne in mind. These are as follows :

(1) The principal aims were the manufacture of cardwire for wool-cards, and the production of such wool-cards. The sale of wire was not permitted, and it is recorded that in 1564 John Williams, one of the masters, had to pay a fine for three of his servants for " selling wyer."

(2) With regard to the sort of wire manufactured at Bristol the only distinction made in the wire-drawers' minute-books is between " coarse wire " and " cardwire."

(3) The most important event in the history of wire-drawing in England was the erection of the wireworks at Tintern, Monmouthshire. The wirehouse was built between the late autumn of 1566 and the end of July, 1567,[10] and was situated on the banks of the Angewe brook, which flows west to east and enters the river Wye north of Tintern Abbey.[11]

The erection of the Tintern wireworks had two far-reaching effects, (1) economically, as the Society of the Mineral and Battery Works, which owned the works, was given the exclusive monopoly of manufacturing iron and brass (" latton ") wire, and (2) technically, as water power was there applied to wire-drawing for the first time in England.[12] In these works elaborate machinery was employed, and this has been partially described by John Ray, the naturalist.[13] All these engines, beginning with the four (later six) hammers for forging iron into rods, were driven by water-wheels. With this machinery, the use of which was also included in the monopoly, a much greater variety and improved quality of wire could be produced. According to depositions made in 1605, twelve different sorts of wire, from the coarsest, known as " Boultock," to " fine fine " were made at Tintern, compared with the four varieties made in England before the erection of the Tintern works ; these four were coarse wire, the finest of them being middle wire.[14]

In the depositions of 1605 already mentioned, several wire-drawers called as witnesses declared that before the application of water power at the Tintern Works in 1567 " all English wyer was made and drawn by mens' strength with engines called " brackes," or " brakes." According to opinion generally accepted, the brake was a hand-lever by means of which iron rods were drawn through a wortle or drawplate made of iron or steel. From this the term " breaking-down," still in use today, has been derived.[15] The man who worked the brake was called a brake-man, and he received the iron rods from the smithers.

The smither, *i.e.*, the smith, in his forge reduced iron bars with the hammer into rods. In the Bristol

[8] Bristol Central Library, MSS. 5029–30. The author is greatly indebted to the City Librarian, Mr. James Ross, M.A., F.L.A., for supplying the accompanying photostat copy of a page from these manuscripts.

[9] M. Dormer-Harris, " The Coventry Leet Book," pp. 180–183. London, 1907–13. (Reprinted by L. F. Salzman, " English Industries in the Middle Ages " (new edition), pp. 329–331. Oxford, 1923.)

[10] Public Record Office, State Papers Domestic, vol. 40, No. 63, and vol. 43, No. 31.

[11] National Library of Wales, Aberystwyth; Badminton Manorial Records, No. 1524. The documents comprising the Badminton Collection are the property of His Grace the Duke of Beaufort, to whom the thanks of the author are due for permission to study the records.

[12] H. Hamilton, " The English Brass and Copper Industries to 1800," p. 19. London, 1926.

[13] J. Ray, "A Collection of English Words not Generally Used " (fourth edition), pp. 140–141. London, 1768.

[14] Public Record Office, Exchequer Depositions by Commission, Hilary 2 James 1, No. 12.

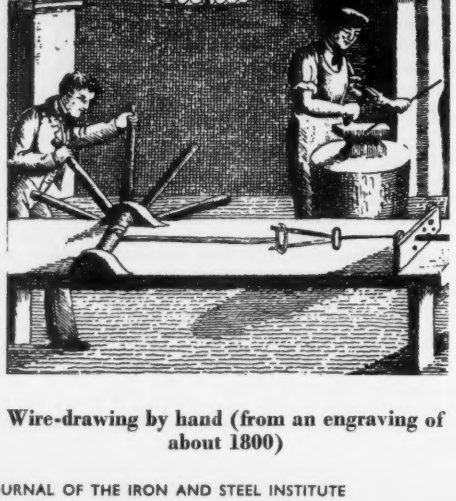
[15] P. Longmuir and T. Kenworthy, " Notes on Early Wire-Drawing Practice," *Engineering*, 1913, vol. 95, p. 542.

Company's Charter of 1469 a handwritten addition inserted a little later, but still contemporary (about 1480), states that every master of the craft being a householder and burgess of Bristol was entitled to have his own forge in the town "therein to have men wirking their wire tools instruments and all other that (be)longeth and appertaineth to their crafts and occupations and none other." The forge referred to is that in which the smither forged the iron bars into rods and rounded them. Probably the brakeman also worked at this forge, reducing the rods into a coarse wire of the thickness of the little finger.

At Coventry in 1435 the brakeman's product was either sold for hook-wire or given to the "girdleman" for further reduction to the thickness of a great pack-thread, this being accomplished by means of an instrument termed the "girdle." The method is described in a letter written by T. Evelyn (Commissioner of the Privy Seal) and dated 8th February, 1676.[16] In the letter the drawing of wire at the brass-mills in the parish of Wotton (Surrey) is described. The wire was drawn by "men sitting harnessed in certain swings, taking hold of the brass thongs fitted to the holes (*i.e.*, the holes of the draw-plate), with pincers fastened to a *girdle* which went about them; and then with stretching forth their feet against a stump they shot their bodies from it, closing with the plate again."[17]

[16] A reproduction of the letter is prefaced to T. Aubrey's "The Natural History and Antiquities of the Country of Surrey," vol. 1, London, 1719.

[17] The opinion expressed by Longmuir and Kenworthy (*loc. cit.*) confining the girdleman's activities to annealing the wire cannot be upheld; various records of the Tintern works supply ample evidence that alternate annealing of the wire and laying it in water were repeatedly applied during the various stages of wire-drawing.



Wire-drawing by hand (from an engraving of about 1800)

Women workers in wool, fifteenth century. The woman in the centre has two wool-cards in her hands

Compared with the brake, the girdle was a definite advance, as power was more advantageously distributed. The method did not compare favourably, however, with that of wire-drawing by means of water power, as at the Tintern works, as the pincers used with the girdle as well as with the brake left impressions on the wire produced.

In the minute-books of the Bristol wire-drawers no brakeman is mentioned after 1562 and no smither after 1567, so it would appear that girdlemen and cardwire-drawers were then the only workers engaged in wire-drawing at Bristol. However, the coarse wire previously drawn by the brakeman was the material required for further reduction both by the girdleman and the cardwire-drawer, and it thus had to be procured from elsewhere. The place from which it was obtained was Tintern, and the records of the Tintern wireworks supply evidence of wire being sent to Bristol, beginning with the year 1568. In the extensive correspondence maintained between William Humphrey (one of the founders of the Tintern wireworks) and Lord Burghley (the great statesman of the Elizabethan era) there is a letter, dated 27th November, 1568, which records that the wire made at Tintern suited the craftsmen of Bristol and Gloucester and "that they have bargained with our factor for so much as shall serve their whole trade."[18] According to a record of between 1585 and 1590,[19] wire was sent from Tintern to London,

[18] Public Record Office, State Papers Domestic, vol. 48, No. 43.

[19] British Museum, MS. Titus, *B*V, folio 369.

Bewdeley, Gloucester, and Bristol ; from Bewdeley it was sent to the Midlands.

The Tintern wireworks increasingly supplied the various wire-drawing crafts of the country with wire to be afterwards mainly drawn into cardwire for wool-cards, which were indispensable in the wool industry, England's staple industry since the fourteenth century. Reduction of the middle wire drawn by the girdlemen to cardwire was done by the cardwire-drawer, corresponding with the fine-wire-drawer of today. Wool-cards were made of cardwire by the cardmaker, and were wooden instruments fitted with wire spikes set in leather.

Carding the wool must be distinguished from combing it. In carding, short-fibred wool was placed between two cards, which were worked in every direction in order to bring the wool into a fluffy mass of fibres. Carding accentuated the cohesive faculty of the short-fibred wool used for woollen yarn. In combing, the short fibres were removed and the long fibres were laid in straight lines. After combing, the long-fibred wool was used for the production of worsted.[20]

As previously mentioned, the importation of wool-cards had been forbidden by Edward IV in 1463. His successor on the throne, Richard III, re-enacted the prohibition in 1483, but with one exception, namely, " Roan cardes," *i.e.*, wool-cards manufactured in Rouen, in Normandy.[21] This signifies some superiority of contemporary wire-drawing in France, and the importation of wool-cards from Rouen continued till late in the following century. For example, in the deposition of 1605, previously referred to, a London ironmonger, one John Challoner, declared that " the greatest part of wool cards spent in England before the erection of the works at Tyntern, were had from Roane in Normandy." Challoner himself, as a merchant, had brought into the country " great store of wool cards " for many years before 1597, when Queen Elizabeth prohibited the importation of " cardes for wooll out of France and other foreign parts."[22] The Royal prohibition was enacted on behalf of the " cardmakers and cardwyerdrawers of the Cities of London, Bristol, Gloucester, Norwich, Coventry and many other cities and towns," but the main instigator was the Society of the Mineral and Battery works, on behalf of its works at Tintern.

Despite this prohibition, which considerably strengthened the Society's position on the inland market, the output of wire from the Tintern wireworks considerably decreased in the last decade of the sixteenth century and in the first three decades of the seventeenth. In 1594 and the years following, the wireworkers of London complained of insufficient supplies of wire from Tintern. The main reason was that the works had been let on lease since 1570 and the lessees had tried to obtain as much profit as possible by means of increasing their prices and lowering the quality of their produce.[23]

After a short interval of fifteen years, during which the Society of the Mineral and Battery Works had the Tintern works in their own hands, the works were leased out again in 1613. As a result the same complaints arose anew, and they became almost general throughout the country when in the sixteen-twenties the Society aimed at a Royal Act prohibiting the importation of foreign wire, wool-cards, and other articles made of wire. The Court-Books of the Society[24] for these years are full of complaints, not only from the London wireworkers but also from many other parts of the country, such as Essex, Suffolk, and Bristol, where wire obtained from Tintern was drawn into cardwire for wool-cards.

According to their guild minute-books, deputies of the Bristol wire-drawers and cardmakers repeatedly went to Tintern between 1624 and 1630 (in 1629 they went five times), to remonstrate against the insufficient supply of wire and the increase in price. The contents of one of their petitions are preserved in the Society's Court-Books for 1631 (May 20th). In this petition the cardmakers and wire-drawers of Bristol complained " of the want of wire, alledging that it was kept in by the Company's farmers (*i.e.*, the lessees of the Tintern wireworks) and the prices thereof enhanced."

The scarcity of wire incited one of the Bristol wire-drawers, John Bisse, to set up iron-wire works in the Forest of Dean. Bisse managed to interest Sir John Wintour, one of the great ironmasters of the Forest,[25] in his enterprise, and bought large quantities of nail-rods from him to be drawn into iron wire. The Society of the Mineral and Battery Works, regarding this as an infringement of its monopoly, demanded (11th February, 1631) that Sir John suppress the new works. In his answer Sir John pointed out that the wire was drawn with a brake, the use of which did not infringe the Society's patents, as no engines driven by water power had been used. Despite this support, John Bisse submitted to the Society on the 20th May, 1631, and gave up his wireworks.[26] The power of the Society had been too strong to be opposed by a single enterpriser, in spite of the excellent chances offered by the state of the wire market, where iron wire was in great demand.

The Society's efforts to obtain prohibition of the import of foreign wire and wool-cards were crowned with success when King Charles I prohibited such importation by a Proclamation of 7th May, 1630. In fact, the Proclamation went even further by prohibiting the sale of old wool-cards,[27] which were frequently bought, trimmed-up, and then sold again for new.

[20] H. Heaton, " The Yorkshire Woollen and Worsted Industries," Oxford Historical and Literary Studies, vol. 10, pp. 261–262. Oxford, 1920.

[21] The Statutes of the Realm, vol. 2, p. 495. London, 1816.

[22] The Statutes of the Realm, vol. 4, p. 914. London, 1819.

[23] H. Hamilton, *loc. cit.*, pp. 38–40.

[24] The Court-Books are in the possession of Messrs. Nevill, Douce and Co., Ltd., London. Only two volumes, namely vol. 1 (covering the period from 1565 to 1585) and vol. 3 (relating to the years 1620 to 1713) have been preserved ; unfortunately, the second volume is missing.

[25] Sir John Wintour owned three furnaces and forges in the Forest and, in addition, later (1640) bought four furnaces and three forges there belonging to the King (*see* Rhys Jenkins, "Ironmaking in the Forest of Dean," *Transactions of the Newcomen Society*, 1927, vol. 6, pp. 50–52).

[26] Court-Books, vol. 3, folios 53, 56–57.

[27] H. Hamilton, *loc. cit.*, p. 50.

The terms of the Royal Proclamation were diligently observed by the Bristol wire-drawers and cardmakers, in close co-operation with the Society. In 1630, at Christmas, the Bristol wire-drawers seized 500 cwt. 1 qr. of foreign wire brought from abroad into Bristol by one William Payne. Such an operation was sometimes met with strong resistance, as, for example, in the case of Richard Coulston, a master of the guild who had bought a further hundredweight of this imported wire. When the wire-drawers endeavoured to confiscate it, "he kept it from them by violence and gave them many scurrilous and base speeches."[28]

Seizure of "old cardes" is mentioned repeatedly in the minute-books of the Bristol wire-drawers' guild; for example, it is recorded that in 1590 old cards were searched for by the Constable of the City and when found they were burnt in the Hall of the guild.

Sometimes the motive for fraudulent conversion of old cards into new ones was sheer penury. Evidently this was the case when old cards were seized from William Hunt, one of the masters of the guild, in 1633. Hunt obviously was in distressed circumstances as he had been unable to pay his annual contribution to the guild in the preceding two years.

The effective efforts of combating the conversion of old wool-cards into new cards and importation of cardwire from abroad (mainly from Flanders) considerably promoted the prosperity of the Bristol wire-drawers. The number of the masters had never been as high as in the decades following the Royal prohibition of 1630. In the defensive war against illegal importation from abroad the Society of the Mineral and Battery Works was actively aided by the Bristol guild. In 1654 the Society received several letters from Bristol complaining that divers quantities of Flemish iron wire had lately been imported into the city "to the great prejudice of the home manufacturer of iron wire and wool cards made thereof." The Society obtained a warrant for seizure and authorized John Cuttford and Thomas Gill of Bristol to proceed accordingly.[29]

The effect of this step does not seem to have been of long duration, for on 11th February, 1655, the Society received information that "Flemish card wire ready drawn for making of wool cards and other foreign iron wire have lately been imported and daily are imported from beyond the seas into the Cities of Bristol and Exeter and into divers other parts of the country within the several counties of Somerset, Dorset, Devon and Cornwall." The Society pointed out that the cards made of foreign wire were not in any way "so stiffe or serviceable as the cards made of our owne wyer drawne in this Nation," and they appointed William Evans and James Merediff, both wire-drawers at Bristol, regularly to search for such imported wire and to render account of their activities in pursuance of this task. The duties imposed on the two wire-drawers were not confined to Bristol, but also extended to Exeter.[30]

[28] Court-Books, vol. 3, folio 53.
[29] Court-Books, vol. 3, folios 110*b*–111.
[30] Court-Books, vol. 3, folio 117*b*.

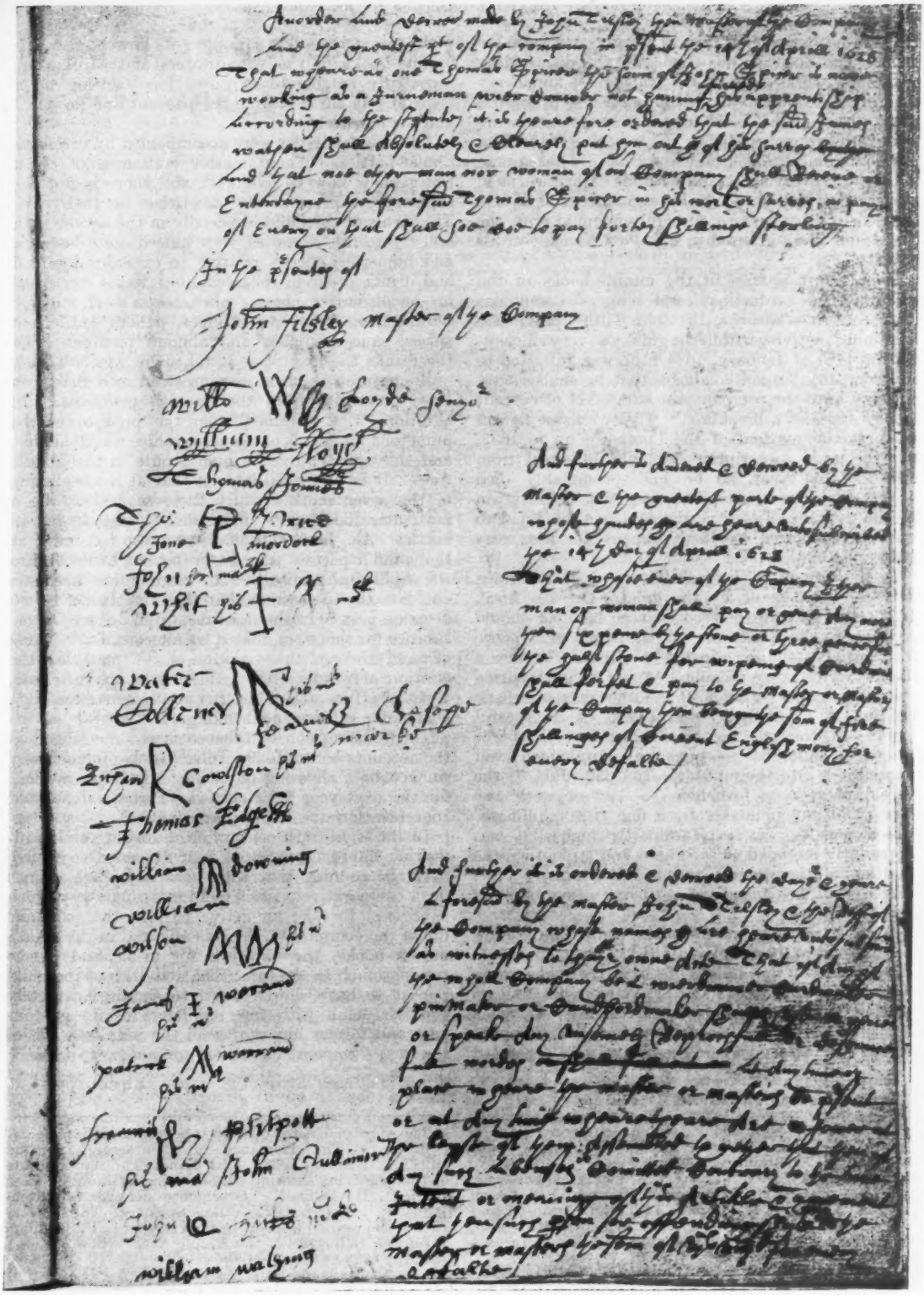
In the following four years the Society incited the wire-drawers and cardmakers of the cities of London, Bristol, and Gloucester, and also those of the counties of Essex, Kent, Sussex, and Yorkshire, to make petitions against the importation of foreign cardwire and of wool-cards made of Flemish wire, and "the translating of old cards and putting the overworne wire into new stocks and new leather."[31] By these constant efforts they obtained two Proclamations from King Charles II, one of 8th May, 1662,[32] and the second of 3rd May, 1678,[33] re-enacting the previous prohibitions issued since 1463.

Some of the guild's members rose to prominent positions in public life, *e.g.*, the cardmaker Vawer, who was an alderman of the City of Bristol when he died in 1621 and, according to the minute-books, had been mayor in 1601. The best known of all these wire-drawers, cardmakers, and pinners at Bristol is John Tilsley, whose memory has been kept alive in poetry and history. In a local ballad he is extolled as "Gentle Johnny" Tilsley who "came and invented pins in Gloucester" after he had manufactured them at Bristol. This event is supposed to have taken place in 1626, when Tilsley entered into an indenture with the mayor and citizens of Gloucester by which he was allowed to set up the trade of pinmaking there and was lent £200 to do so; he was also provided with thirty boys to be trained in pinmaking and to work for him. Tilsley agreed to pay each boy 12*d*. per week during the first year, 15*d*. in the second year, and 18*d*. in the third year of their employment, the same terms granted to the boys in Tilsley's employment at Bristol.[34]

The employment of children for pinmaking was one of the means of combating poverty and mendicancy in the early seventeenth century. It was used by the Corporation of Bristol as early as 1607, when they advanced a loan to Thomas Nash, pinmaker, for engaging poor children in his trade. Poor boys were also employed for pinmaking by John Tilsley in 1623, when £100 were advanced to him by the Corporation, but Tilsley's business failed and he became insolvent.[35]

Pinmaking became more important in the beginning of the seventeenth century, and the pinmakers of Bristol were accordingly more active than they had previously been. The supply of brass wire used for pinmaking also came from Tintern, and was no more sufficient than that of iron wire. This encouraged the wire-drawer John Bisse, previously mentioned, together with William Berry (another Bristol man), to set up works for the production of brass and brass wire at Stapleton, close to Bristol. This was an infringement of the monopoly of the Society of the Mineral and Battery Works, especially as Bisse and Berry used water-wheels and other engines and tools exclusively patented to the Society; in addition they

[31] Court-Books, vol. 3, folios 122*b* and 125*b*.
[32] The Statutes of the Realm, vol. 5, p. 412. London, 1819.
[33] Court-Books, vol. 3, folio 183.
[34] J. J. Powell, "Gloucestriana," pp. 20–21. Gloucester, 1890.
[35] J. Latimer, "The Annals of Bristol in the Seventeenth Century," pp. 82 and 84, Bristol, 1900.



Page from the guild minute-books, showing the signatures of John Tilsley and other masters of the Company in 1626, with their marks

had enticed one of the Tintern workers to work for them. The Society thus requested the dismantling of the new works in 1629, but when Bisse and Berry came to make their peace with the Society it granted them a lease of the works for ten years, commencing from 29th September, 1629. The lease was for making " yellow wire," but no iron wire. Bisse did not appear to have been very successful with his enterprise, as in December of the same year his annual rent of £5 was reduced to a peppercorn, a merely nominal rent, the concession being granted to him " on account of his poverty."[36]

From many entries in the minute-books of the wire-drawers,' cardmakers' and pinners' Company, it appears that Tilsley's (the John Tilsley previously mentioned) activity within the guild was very efficient. On the 17th of January, 1624,[37] he was admitted to the Company " upon condition that he shall satisfy and pay unto the company the sum of £1 of currant money and also a breakfast." Tilsley's name figures amongst the masters of the Company up to 1633, but the usual subscription was not obtained from him for that year, so he had presumably died or left the town ; his name does not occur again in the records. Tilsley had been one of the two wardens appointed by the Company for the years 1626 and 1627.

In the time of Tilsley's activity several important decisions were made by the guild. On 4th April, 1628, the Company decreed that no member should pay more than " sixpence by the stone or 3 pence for the half stone for wipeing of cardwire," under a fine of 5*s*. for every default. Wiping meant scouring the wire to remove scale.[38] Another decree forbade the use of " unsemely, reproachful or disgraceful words " in the presence of the masters. This was evidently intended to put the journeymen and apprentices into their places. In 1630 (July 7) the wire-drawers were forbidden to " set at work any servant of any pinmaker by a fine of 40 shillings," which penalty was extraordinarily high and was apparently intended to safeguard and strengthen the position of the pinners within the Company ; this decree may be considered as being a symptom of Tilsley's influence.

Social gatherings and festivities constituted an important part of the guild's activities. The main events of this side of the guild's life were the midsummer festivities on St. John's and St. Peter's eves and, up to the Reformation, Corpus Christi day. On such occasions the guilds marched with banners and music through the streets, where the houses were decorated with tapestries and garlands of flowers.[39] The minute-books of the wire-drawers and cardmakers repeatedly enumerate expenses for " setting up a pageant," or for " bearing the pageant and flowers," and for minstrels.

All these festivities were accompanied by extensive dinner-parties. These master craftsmen of olden times knew how to live well, and there is not the slightest symptom of any asceticism on their part. The meals of the guild, especially in the seventeenth and eighteenth centuries, were indeed quite luscious, and numerous entries relating to expenses for food and drinks occur in the accounts. Items concerned are bread, butter, cheese, cakes, bacon, beef, mutton, pork, geese, turkeys, partridges, pullets, garlic and spices, sauces, apples, and almond puddings. Of the drinks the first place is taken by wine. This is quite natural, as wine was imported into Bristol in large quantities from the Spanish peninsula. In addition, wine obtained from the produce of the numerous vineyards of Gloucestershire was available, and this wine enjoyed a high repute in the Middle Ages. It is of special interest that at the beginning of the seventeenth century there seemed to be a particular liking for " muscadell " wine served in bottles. Ale, beer, and cider were also consumed at the guild's parties, the latter beverage not before the eighteenth century. In reading the accounts one gets the impression that these craftsmen let no occasion pass by without a substantial drink. Opportunities for this were offered by almost all the events of guild life, *e.g.*, the reception of new members, the election of wardens, the rendering of accounts, etc. Even the funerals of brother craftsmen afforded a chance for subsequent drinking.

The consumption of tobacco is not mentioned in the accounts before 1659. Tobacco was preferentially smoked on " choosing day " *i.e.*, when the wardens for the next year were elected. Perhaps it assisted concentration at such an important act.

In the eighteenth century wire-drawing and cardmaking improved so much and extended so widely over the country that there was not much chance for a comparatively small guild in a single town such as Bristol to take an active part in the economic life of the community. This is reflected in the guild's minute-books, the expenses for meals and drinks coming much to the fore. The activities of the guild appear to have slowed down to those of a merely convivial club with few reminders of its glorious past and former importance in the industrial life of the city. *Tempora mutantur et nos mutamur in illis.*

[36] Court-Books, vol. 3, folios 37*b*–46.

[37] It should be noted that in the era being discussed the years were reckoned as commencing on the 25th March. In modern chronology, therefore, this date would be given as 17th January, 1625.

[38] Comparison with a list of the weekly expenses for wire-drawing at Tintern (British Museum, Lansdowne MS. 56, No. 47) is of interest. At Tintern train-oil and tallow were used, and at Bristol evidently wax also, as occasionally one of the masters is referred to as a " waxman."

[39] J. Latimer, Sixteenth-Century Bristol, pp. 5–6, Bristol, 1908.

The view of Bristol in 1576 is reproduced from H. G. Selfridge, " The Romance of Commerce " (second edition). London, 1923 : John Lane. The reproduction of the engraving showing wire-drawing by hand is taken from D. H. Döhner, " Geschichte der Eisendrahtenindustrie." Berlin, 1925 : Julius Springer. The illustration of the women workers in wool is from L. F. Salzman, " English Industries of the Middle Ages " (new edition). Oxford, 1923 : Clarendon Press.

An Examination of Blast-Furnace Scaffolds and Scaffold-Forming Materials

By J. H. Chesters, D.Sc.(Tech.), I. M. D. Halliday, B.Sc., A.R.T.C., and J. Mackenzie, B.Sc.

Preliminary examination of a number of blast-furnace scaffolds suggests that they consist of : (1) Altered brickwork, frequently displaced several feet from its original position, probably by carbon deposition in the lining ; such brickwork normally shows attack by alkalis, being rich in potassium aluminium silicates such as kaliophilite and kalsilite ; (2) fused or partially fused agglomerations of slag, coke, iron oxides, and reduced iron (together with potassium aluminium silicate compounds), adhering to the refractory wall. The extent to which the alkali material is responsible for scaffolds is not clear, but such deposition is likely to promote both consolidation and adhesion.

It has been shown by laboratory tests that (*a*) all the iron ores examined soften at low temperatures and adhere to fireclay bricks after heating to temperatures below the melting point of the ore, (*b*) both fireclay bricks and the aluminium silicate material in the burden suffer a drop in melting point when attacked by alkalis, (*c*) iron ore does not adhere to carbon brick after heating in contact with it and subsequently cooling, and (*d*) carbon bricks burn fairly quickly at 1000–1200° C. in CO_2, but the rate of combustion falls off rapidly with a drop in temperature or with the admixture of carbon monoxide or nitrogen.

The trial of carbon bricks in blast-furnace stacks to reduce scaffolding is therefore recommended.

A RESEARCH man called in for the first time to inspect a blast-furnace scaffold was reduced in his report to such vague observations as "the top part consisted of loose muck." His unscientific language met with rebuke, but having seen several such scaffolds ourselves we feel extremely sympathetic. The refractory technologist accustomed to inspecting the almost fairy-like beauty of a worn-out open-hearth furnace, with its stalactites hanging from the roof and its beautiful multicoloured and clearly zoned bricks, can scarcely fail to be horrified at the spectacle of a worn-out blast-furnace stack in process of demolition. The more samples he takes the more confusing the problem becomes and the more he looks like a coalminer. What is true of one side of the furnace is not always true of the other, and he is perpetually faced with the question of how much of the material he is sampling has fallen from somewhere else in the furnace and to what extent the samples themselves have been affected by the water normally employed in cooling-down after blowing-out.

I—THE STRUCTURE OF SCAFFOLDS

(*a*) GENERAL

In view of the complications mentioned it is hardly surprising that there does not appear to be any clear description of scaffolds in the literature. Many references have been made to the scabs formed on linings, *e.g.*, in the numerous papers from the British Refractories Research Association and associated with the names of Green, Hugill, Rigby, Woodhouse, and their co-workers, but no attempt has yet been made to explain the picture as a whole. Šárek[1] and Elliot[2] have both discussed the subject at some length, but their approach is operational rather than mineralogical.

Perhaps the paper of most direct interest is that by Kraner,[3] who includes an ingenious diagram showing the concentrations of a number of different minerals at different heights in the furnace at the brick–scab interface. The dominant minerals are those in the kaliophilite ($K_2O \cdot Al_2O_3 \cdot 2SiO_2$)–nepheline ($Na_2O \cdot Al_2O_3 \cdot 2SiO_2$) series, but leucite and the alkali, calcium, and magnesium carbonates are also found in considerable quantities. The diagram shows appreciable scaffold formation approximately two-thirds of the way up the stack from the mantle to the bell. Kraner says that the breakdown of the refractory in this region is mainly due to carbon deposition and alkali attack, observations which are in line with the experience in this country. He suggests that the initial weakening of the lining is due to carbon deposition, but that scabs adhering to the brickwork cause the weakened face to fall away. He also refers to the scab "further down as consisting of stock, alkalis, and small lumps of brick which find their way into the descending burden." Irregularities in the slag analyses, especially in the alumina content, are attributed to the sloughing-off of brickwork damaged by carbon disintegration and alkali attack. Kraner's paper contains a bibliography consisting of some 75 references to refractories service conditions in the blast-furnace, and this should serve as a useful introduction for those wishing further to pursue the literature on this subject. In the present paper the authors' own experiences will be presented without any serious attempt to interpret them other than in severely practical terms.

(*b*) SCAFFOLD IN NO. 1 FURNACE, FRODINGHAM

Vertical and horizontal sections through a scaffold in No. 1 furnace at Appleby-Frodingham are shown in Figs. 1 and 2, respectively. This was one of the largest scaffolds experienced at these works. The maximum thickness of the build-up was in the zone directly above the slag notches, the constriction at the minimum-area point being equivalent to about 50% of the original cross-section. Above the scaffold

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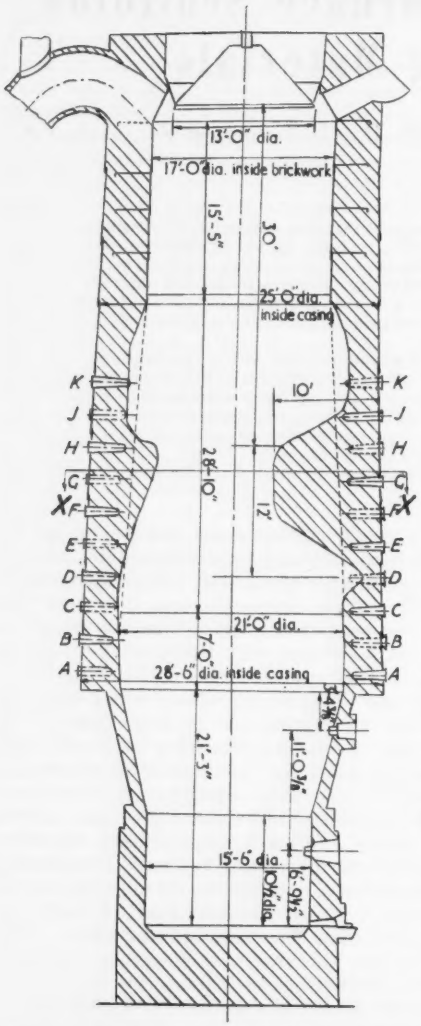

Fig. 1—Vertical section through scaffold in No. 1 furnace, Frodingham, August, 1945. The section at *XX* is shown in Fig. 2

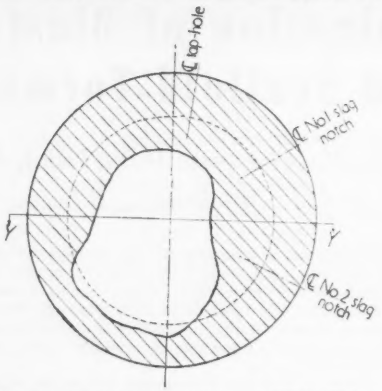

Fig. 2—Horizontal section at *XX* in Fig. 1. The positions of tap-hole and slag notches are approximate

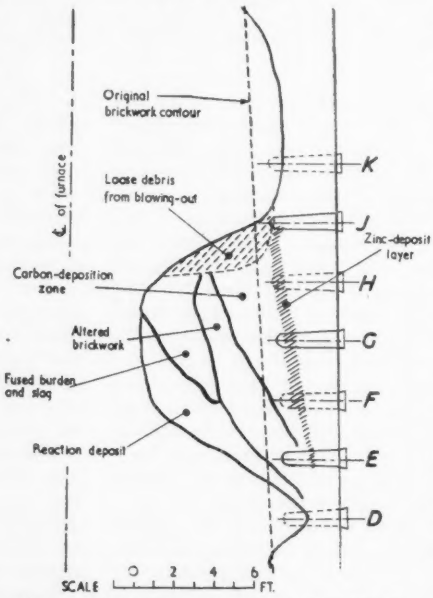

Fig. 3—Diagrammatic sketch of zones in scaffold in No. 1 furnace, Frodingham, August, 1945

the armoured throat was in excellent condition and the brickwork had maintained its original thickness, while below the scaffold the bosh brickwork had become very thin; Fig. 1 merely reproduces the original furnace lines of the hearth and bosh. The vertical position of the scaffold in the stack is characteristic of Appleby-Frodingham scaffolds, which usually form at about 30–40 ft. below the bottom of the hopper. In the horizontal plane the maximum scab formation can occur at almost any position.

History of Formation

The furnace concerned was blown-in in 1939 and the scaffold shown is regarded as the second of the campaign, the first having been successfully "tuyered-off." The present scaffold had been on the stack for about two years, attempts at tuyering-off having been unsuccessful.

Sampling

The sampling of a scaffold is extremely difficult because of the extraordinary variations in composition and hardness. Attempts have been made to drill cores in scaffolds, but so far without any real success. The present scaffold was broken down, using pneumatic tools, bars, picks, etc. It was soon evident that the scaffold consisted of a large number of different zones; at the sampling point these were roughly as shown in Fig. 3. Each of the three main zones itself contains sub-zones, and a list of those found in a typical section is given in Table I, together with a description based on visual examination. There is no guarantee that this zone formation is characteristic of scaffolds in general, but a description of the zones and of their constitution as revealed by laboratory examination may be worth while if only to demonstrate the extreme complexity of the scaffold problem. The main zones can be roughly considered as being made up of (*a*) altered brickwork, (*b*) fused burden and slag, and (*c*) reaction products from the furnace. The loose material resting on top of a scaffold is considered to be merely debris that has fallen there during the blowing-out process.

Examination of Samples

Many of the samples were found to be in a moist condition owing to the hygroscopic nature of the constituents and possibly some water absorption during the blowing-out operation. This may have resulted in some modification of the original constitution. The results of chemical analyses and X-ray examinations are given in Tables II and III. The *A* series of samples reported in Table II represents as completely as possible the zones through the full cross-section of the widest part of the scaffold, while

Table I

DESCRIPTION OF ZONES FOUND IN THE SCAFFOLD OF NO. 1 FURNACE, FRODINGHAM, AUGUST, 1945

Zone	Brief Description
Mauve zone next to casing	Hardly changed brickwork. Mauve colour due to reducing conditions
Heavy zinc-deposit layers	Yellow crystals of a zinc compound (needles) in joints and in vertical cracks in the brick (mauve zone). Considerable number of cracks occur at irregular intervals
Pyrophoric carbon belt	Very finely divided soot-like carbon dust, which burns spontaneously on exposure to air at low temperature (*e.g.*, in sampling). Appeared to contain small pieces of bright and shiny coke
Carbon-deposition zone	Disintegrated brickwork containing much carbon
Dense hygroscopic zone	Very hard dense layer. Brick texture lost; very hygroscopic on exposure to air
White heterogeneous zone	Several relatively soft thin layers containing white deposit believed to be alkali chloride. Fairly hygroscopic
Green zone	Fairly dense bright chrome-green zone of the texture of sugar in mass. Only slightly hygroscopic
Mass of slag and/or decarburized-iron–slag–coke mixture	Irregular lumps adhering to tip of scaffold green zone. Probably formed by tuyering-off actions, as blow-holes were present, but might be due to burden accretions
Grey heterogeneous zone	Several thin zones alternately hard and friable and of grey slaggy appearance. Tend to be hygroscopic
" Cheesy " zone	Very soft yellow cream deposit of high porosity. Salt-like texture and tends to be hygroscopic
Grey slag zone	Very hard dense grey slag, slightly hygroscopic
White slag zone	Dense slaggy-type material; not hygroscopic and fairly hard

the *B* series in Table III is from the opposite side of the stack, where the scab was much thinner. Table IV gives the results of X-ray examination of brickwork samples taken from " living furnaces " at definite time intervals after the campaign.

Comments on the Results

Consideration of the results of the examinations gives rise to the following comments:

(1) X-ray examination indicates the presence of zinc oxide and zinc silicate compounds in the form of green crystals, largely confined to the jointing material of the brickwork. How far the deposition of these compounds may have contributed to the disintegration of the brickwork is a matter concerning which there is considerable doubt, as the bulk of the brickwork appears to be constitutionally unchanged and reasonably hard and sound.

(2) The pyrophoric carbon zone adjacent to the brickwork is substantially carbon of the soot and/or coke types, but containing relatively large amounts of mineral matter, which may come mainly from the ash residue of the coke.

(3) The remaining zones, from the " carbon-deposition zone " to the " white-slag zone " on the inner face of the scaffold, may be classified broadly into two main types, as follows:

(i) The outer zones, *i.e.*, from the " carbon-deposition zone " to the " slag–coke–iron " mass, contain high proportions of alkalis (largely potash), silica, and alumina, with only relatively small amounts of burden materials and free carbon. The bulk chemical analyses of these various zones differ only slightly, and in all zones the molecular ratio of the potash, alumina, and silica contents indicates the possibility of a compound of the $K_2O \cdot Al_2O_3 \cdot 2SiO_2$ type, the occurrence of which in these zones would account for the main mass of material. X-ray examination confirms the presence in major amounts of general compounds of this type, *e.g.*, kalsilite and kaliophilite.

The absence of lime and the low contents of iron oxide in the analyses of the outer zones of the scaffold adjacent to the inwall suggest very clearly that these zones originate from the attack of condensed alkalis on the brickwork of the stack, leading to the formation of compounds of the $K_2O \cdot Al_2O_3 \cdot 2SiO_2$ type. It is possible that the amount of material in this zone has been added to by erosion or disintegration of the brickwork at higher levels. At this stage of the examination there is insufficient evidence to indicate whether the alkali attack on the brickwork is a primary or secondary effect of the scaffold phenomenon or, in other words, to indicate whether the alkali attack occurs before the deposition of the inner zones of burden agglomeration described below.

(ii) In the inner zones, *i.e.*, from the " slag–coke–iron " mass to the " white-slag " zones, the character of the accretion changes. Burden constituents such as lime and magnesia begin to appear in the general analyses, together with substantial amounts of metallic iron and iron oxides. In addition the alkali contents of the several sub-zones of this portion of the scaffold are lower than in the outer zones. At the same time the silica and alumina contents are lower, and since the burden materials contribute towards the general total of these constituents the presence of potassium aluminium silicate cannot be confirmed either on the basis of the molecular ratio of the constituents or by X-ray examination.

The inner zones appear, therefore, to have originated largely from the furnace burden. The latter, owing to partial reduction and fusion, becomes adherent to the brickwork, which may or may not have already been seriously attacked by alkalis. The general constitution of this zone consists of iron oxides and reduced iron, with

Table II

CHEMICAL ANALYSES AND MINERALOGICAL EXAMINATION OF SCAFFOLD SAMPLES. *A* SAMPLES (NO. 1 FURNACE)

The analyses given in brackets were carried out at the laboratories of the Appleby-Frodingham Steel Co.

Sample (description, position)	SiO_2, %	Al_2O_3, %	Fe_2O_3, %	FeO, %	Metallic Fe, %	MnO, %	CaO, %	MgO, %	ZnO, %	K_2O, %	Na_2O, %	CO_2, %	Free carbon, %	S, %	Cl†, %	Combined water %	Other Components, %	X-Ray Examination (phases in amount)
Section 1																		
Brickwork:																		
(i) (ii) Two samples of mauve brick	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	(i) Mullite ($3Al_2O_3 \cdot 2SiO_2$), med./large. Cristobalite, med. Quartz, small. Zinc aluminate ($ZnO-Al_2O_3$), small
(iii) Dark grey areas	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	(ii) Mullite, large. Cristobalite, small. Zinc silicate ($2ZnO.SiO_2$), med.
(iv) Green crystals in brick and jointing material	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	(iii) Mullite, med. Cristobalite, small. Quartz, very small. Zinc silicate, med.
																		(iv) Zinc oxide (ZnO), very large. Zinc aluminate, very small
Pyrophoric carbon zone:																		Carbon, crystallinity very poor, typical of coke, soot, etc. Traces of minerals having low crystallinity
(i) Lump	2·40	1·90	8·81	..	..	..	2·03	0·35	..	..	..	..	80·5	..	..	..	..	
(ii) Coke	3·83	2·82	2·20	..	..	..	0·50	0·31	..	..	..	..	86·7	..	..	..	..	
Carbon-deposition zone	32·1	23·7	Total iron (as FeO)	6·8		0·6	Nil	0·8	2·5	20·3	1·1	Nil	5·8	..	..	..	TiO_2 0·8	Three selected portions: (i) Carbon, graphite type, low crystallinity, large. (ii) Kalsilite ($K_2O \cdot Al_2O_3 \cdot 2SiO_2$), very large. (iii) Kalsilite, med.; unknown, med.
	(40·4)	(27·86)	(0·14)	(2·70)	..	(0·075)	(0·25)	(0·70)	(2·46)	(19·8)		..	(3·2)	(0·075)	..	0·50	PbO 0·39	
																	P_2O_5 0·046	
																	TiO_2 1·11	
Dense hygroscopic zone	(34·75)	(22·10)	(0·43)	(2·30)	..	(0·22)	(2·0)	(0·72)	(0·26)	(30·60)		..	(3·3)	(0·288)	..	(1·60)	P_2O_5 0·178	Phase very similar to kaliophilite ($K_2O.Al_2O_3.2SiO_2$) and labelled phase *Y*, med./large. Unknown phase, med.
																	TiO_2 0·93	
White heterogeneous zone	27·85	22·31	Total iron (as FeO)	0·97	..	Nil	Nil	0·56	0·73	25·81	3·54	5·29	3·42	0·085	2·31	2·52	TiO_2 0·28	Phase *Y*
																	$K_3(Fe(CN_6)$ 0·06	
	(27·80)	(21·10)	(0·60)	(0·26)	..	(0·065)	(0·10)	0·43	1·18	(33·90)		(4·7)	(3·6)	(0·096)	3·6*	(2·36)	P_2O_5 0·046	
																	TiO_2 0·214	
																	PbO 0·088	
Green zone:			Total iron (as FeO)															
(i) Soft	30·37	22·45	..	1·62	..	Nil	Nil	0·56	0·92	24·31	2·41	4·19	6·05	0·16	0·11	3·96	TiO_2 0·75	(i) Kalsilite, med./large. Unknown phase, med.
(ii) Hard																	$K_3(Fe(CN)_6)$ 0·003	(ii) Phase *Y*, large. Unknown phase, small
Section 2																		
Slag – coke – iron mass:†	14·96	9·19	Nil	18·33	12·9	0·58	11·36	2·67	Nil	13·27	0·74	2·87	5·75	0·66	0·12	2·65	TiO_2 0·29	
(i) Slag	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	$K_3(Fe(CN)_6)$ 0·003	(i) Unknown phases poorly crystalline
(ii) Iron	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		(ii) Iron, med./large. Perowskite-type phase, small/med. Unknown, small/med.
Section 3																		
Grey heterogeneous zone:																		(i), (ii), and (iii) Iron, small; Unknown phase, large
(i) Inner																	TiO_2 0·07	
(ii) Middle	8·29	4·77	Nil	14·00	6·59	0·15	12·88	1·51	Nil	14·73	0·03	9·04	20·50	0·03	0·48*	4·81	$K_3(Fe(CN_6)$ 0·02	
(iii) Outer	(8·44)	(4·75)	(0·10)	(21·77)	(5·50)	(0·37)	(14·61)	(1·79)	(0·036)	(15·27)		..	(19·37)	(0·016)	(1·51*)	(5·64)	P_2O_5 1·74	
																	TiO_2 0·006	
"Cheesy" zone	19·68	9·69	1·04	22·4	9·82	0·75	19·00	1·57	Nil	6·64	0·40	3·95	0·29	0·04	0·11	1·23	TiO_2 0·09	Iron, small
	(17·55)	(12·10)	(3·55)	(26·10)	(9·50)	(1·26)	(14·70)	(1·62)	(0·05)	(10·70)		..	(1·03)	(0·048)	..	(1·44)	P_2O_5 0·277	Ferrous oxide, small/med.
																	TiO_2 0·165	Magnetite, very small
																	PbO 0·015	Unknown phases poorly crystalline
Grey slag zone	9·88	5·61	2·47	14·5	23·43	0·09	14·50	1·50	Nil	9·60	0·33	7·48	0·30	0·075	0·84*	6·09	TiO_2 0·03	Iron, med.
																	$K_3(Fe(CN)_6)$ 0·003	Unknown phases poorly crystalline
	9·90	6·30	0·14	21·34	15·70	0·37	16·54	2·06	0·045	(15·14)		..	(1·25)	(0·036)	(2·11*)	(8·12)	P_2O_5 0·293	
																	TiO_2 0·005	
White slag zone	(20·0)	(11·47)	(4·30)	(11·20)	(21·70)	(0·68)	(15·95)	(1·13)	(0·25)	(10·30)		..	(0·60)	(0·151)	..	(0·44)	P_2O_5 0·563	Iron, small/med.
																	TiO_2 0·43	Ferrous oxide, small/med.
																	PbO 0·48	Magnetite, small
																		Kalsilite, med.

* Alkali chloride † Analysis of slag-mass cap

slag-forming materials and coke or carbon. The possibility of the presence of smaller amounts of potassium aluminium silicates than are found in the outer zones is not excluded.

(4) Examination of the samples from the accretion on the wall opposite to the main scaffold shows, to a restricted degree, changes in constitution similar to those outlined above.

(5) The results of X-ray examination of the samples of the brickwork from the stack wall of Nos. 1 and 5 furnaces while they were in operation are given in Table IV. Attention is directed to the presence of slaggy matter adhering to the inner working face of a brick sample extracted from No. 1 furnace after 5 weeks' operation. This slag consists essentially of iron and iron oxides, together with gehlenite (calcium aluminium silicate). Potassium aluminium silicate compounds have been observed on a slagged working face extracted from No. 5 furnace after 4½ months' operation.

Preliminary Conclusions

The results of this first examination showed that the presence of alkalis—particularly potash, which doubtless volatilized from the furnace burden—is a major feature of the scaffold found in No. 1 furnace. There appear to be two main zones, in which the character of the accretion differs, namely :

(1) An outer carbon-deposition zone, rich in potassium aluminium silicate formed presumably by alkali attack on the brickwork of the stack wall, together with impurities of burden materials in minor amount.

(2) An inner zone, consisting of a fused, or partially fused, agglomeration of slag, coke, iron oxides, and reduced iron, with possibly smaller amounts of potassium aluminium silicate compounds.

Table III

MINERALOGICAL EXAMINATION OF SCAFFOLD SAMPLES. *B* SAMPLES (NO. 1 FURNACE)

Description and Position of Sample	X-Ray Examination (phases in amount)
Brickwork	Mullite, med./large Cristobalite, med. Quartz, small
Carbon-disintegration zone	Kalsilite, large Unknown, small
Heterogeneous zone	Kalsilite, very large Unknown, trace
Green zone:	
(i*a*) Green (i*b*) Dark grey	Kalsilite, very large
(ii) Green	Phase *Y* (kaliophilite type), large Unknown, small
Outer zone (working face:	
(i) Green	(i) Phase *Y*, very large
(ii) Grey	(ii) Phase *Y*, large
(iii) Dark grey	(iii) Iron nitride (Fe_4N), med./large Magnetite, small/med. Unknown, small

(c) SCAFFOLD IN NO. 9 FURNACE, SOUTH WORKS

An examination of a large scaffold in the stack of No. 9 furnace, South Works, was made during the wrecking of the lining at the end of the campaign.

The furnace was blown-in on the 24th July, 1939, blown-out in October, 1944, in order to reline the hearth with carbon, blown-in again in November, 1944, and finally blown-out (end of campaign) on the 16th December, 1946. The total make of iron was 1,041,970 tons.

Location and Appearance of the Scaffold

The scaffold was of the ring type, located approximately 36 ft. above the tuyere level and extending over a range of 16 ft. from the *E* to the *K* cigar coolers. At its thickest part it extended a distance of 9 ft. from the furnace casing, into the furnace, and consisted of 3 ft. of sound brickwork with a 6-ft. build-up of scaffold material.

A preliminary examination of the stack was made from the furnace top immediately after blowing-out and it was estimated that the clearance at the scaffold area, which at this level should have been 24 ft., was only of the order of 15 ft. and was slightly off centre. During wrecking, a section of the scaffold was exposed and was found to consist of three distinct zones built-up on 2 ft. 6 in. to 3 ft. of sound stack brickwork. Details of these zones were as follows :

(i) A zone of carbon deposition tapering from practically zero at the foot of the scaffold to approximately 3 ft. wide at the top, and consisting of completely pulverized brickwork rich in carbon and showing signs of alkali contamination.

(ii) A "spine" of brickwork running through the middle of the scaffold from the stack lining at the *E* cigar cooler to 6–7 ft. from the furnace casing at the top of the scaffold. The bricks forming the spine varied in length up to 10 in. and appeared to be hinged to the stack lining at the *E* cigar-cooler level. They were black in appearance and showed signs of alkali attack.

(iii) An inner zone of scaffold, consisting of hard semi-fused burden on top with a hard vitrified face on the underside showing signs of gas erosion.

The general appearance of the scaffold section, *i.e.*, the sound brickwork of the original stack lining, the carbon-deposition zone and then, about 6 ft. from the casing, brick ends forming a spine through the scaffold, is shown in Fig. 4, the photograph of which was taken at *H* row of cigar coolers. The inner zone is not visible in the illustration. Above the scaffold the stack brickwork showed the normal wear previously experienced, while below the overhang the stack lining was badly cut back.

Laboratory Examination

The main point of interest in the scaffold was again the appearance of brickwork about 3 ft. inside the original stack contour. Samples of this material were examined in the laboratory.

A typical brick taken from the spine is shown in Fig. 5. This brick was black in appearance and seemed to be heavily impregnated with alkali. Most such samples were bent and showed signs of shearing, with tear cracks, as though the bricks had been

Table IV

MINERALOGICAL EXAMINATION OF BRICK SAMPLES TAKEN AT TIME INTERVALS FROM NOS. 1 AND 5 FURNACES DURING OPERATION

No. 1 furnace blown-in 8/10/45; No. 5 furnace blown-in 11/6/45

Description and Position of Sample	X-Ray Examination (phases in amount)
No. 1 Furnace	
Sample ***H*5** (brickwork; mauve, soft)*	Mullite, med./large Cristobalite, med. Quartz, small
Granular layer on brick surface (apparently jointing material)	Mullite, med./large Cristobalite, med. Quartz, small
Sample ***H*14** (brickwork; pale red colour)†	Mullite, large Cristobalite, small/med.
Brickwork (mauve colour; 1½ in. from slag	Mullite, large Cristobalite, very small Glassy phase present
Brickwork (grey colour; ¼–½ in. from slag)	Mullite, med./large Glassy phase, very prominent
Slag adjacent to burden	Gehlenite, med./large Ferrous oxide, small Magnetite, small Iron, small/med.
No. 5 Furnace	
Sample ***E*1** (brickwork away from slag)‡	Mullite, large Cristobalite, small/med. Unknown, very small
Brickwork adjacent to slag	Mullite, large Cristobalite, very small
Slag (¼ in. thick) on brickwork	Leucite ($K_2O \cdot Al_2O_3 \cdot 4SiO_2$), very large Unknown, small
Slag, outer surface (1/16–⅛ in. thick)	Phase ***Y*** (potash alumino-silicate), very large
Sample ***E*8** (brickwork 1½ in. away from slag)§ ...	Mullite, med./large Cristobalite, med. Unknown, small
Brickwork (light colour, hard, adjacent to slag) ...	Mullite, large Glassy phase also present
Slag	Leucite, very large Unknown, very small
Slag, outer surface	Gehlenite ($2CaO \cdot Al_2O_3 \cdot SiO_2$), med./large Ferrous oxide, small/med. Magnetite, small/med. Iron, small
Sample ***G*8** (Lump; grey pink colour; laminated. Two samples)‖	Kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$), very large; Quartz, very small — Both samples
Brickwork: (1) Normal colour ... ... (2) Dark grey colour	Mullite, med./large; Cristobalite, med./large — Samples 1 and 2

* Sample taken 11/11/45 † Sample taken 11/11/45
‡ Sample taken 28/10/45 § Sample taken 28/10/45
‖ Sample taken 11/11/45

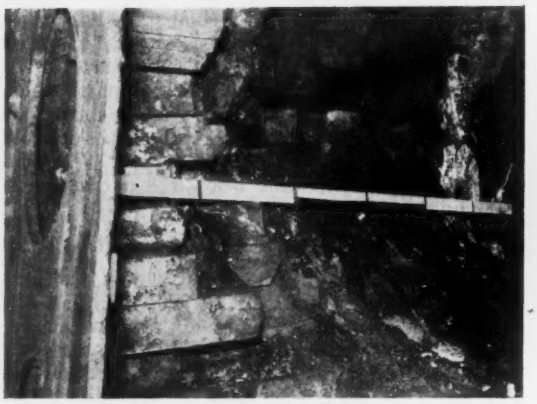

Fig. 4—Section through scaffold in No. 9 furnace, South Works, at *H* cigar coolers, showing " spine " of brickwork on right-hand side

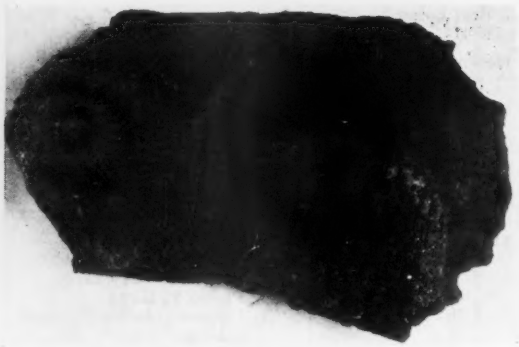

Fig. 5—Brick removed from " spine " shown in Fig. 4

Table V

EXAMINATION OF BRICKWORK IN SPINE OF SCAFFOLD IN NO. 9 FURNACE

	Casing Side (next carbon-deposition zone)	Shearing Zone	Burden Side (next outer scaffold zone)
Apparent porosity, % ...	12·4	6·5	3·7
Bulk density, g./c.c. ...	1·74	1·97	2·31
Apparent specific gravity (by porosity)	1·98	2·11	2·40
After-expansion (2 hr. at 1410° C.)	...	...	Test-piece melted
Refractoriness under load (rising-temperature test, 28 lb./sq. in.)	...	...	Initial softening at 1240° C. Test-piece fluxed badly at higher temperatures
Melting point, °C. ...	1420	...	1340
Chemical analysis:			
SiO_2, %	15·3	17·7	36·9
Al_2O_3, %	14·35	15·48	29·8
Alkalis, %	32·8	33·8	19·4
Carbon (free), % ...	14·0	11·45	8·2
Lead, %	1·70	0·54	...
Total Fe, %	0·95	0·80	2·0
Mineralogical examination	Kaliophilite (large), gehlenite (small/med.). Other phases unidentified, but present in only small amounts	Gehlenite possible. Other phases (majority) not identified	Mullite (large), potassium chloride (med.); potash feldspar possible

rather soft during the working of the furnace and had bent under the load of the scaffold.

The results of laboratory examinations are shown in Table V. The main feature of these results is the obvious alkali contamination of the brickwork, which accounts for the decreased refractoriness and the lowering of the refractoriness-under-load value. The alkali content is highest, as would be expected, at the point where the bricks show tearing. In conjunction with X-ray analysis, the chemical analyses also show that the burden side of the spine is the least attacked, mullite still being the main constituent present. The alkali, coming from the burden as potassium chloride vapour, presumably penetrates to a temperature zone suitable for combination with the brick and subsequent crystallization of complex potassium alumino-silicates. The occurrence of lead is interesting and, owing presumably to the high volatility of this element, is at a maximum concentration furthest from the burden face. It will also be seen that there is a gradation in the free-carbon content through the brick, this being highest at the casing end, *i.e.*, next to the large zone of carbon deposition. Gehlenite was also found as a constituent in the brick, showing that slag formation takes place at this level in the furnace. Little significance can be attached to the peculiar melting-point figures, since it was found impossible to prevent a low-melting-point liquid (probably high in alkali) draining out from the test cone, thus giving false values.

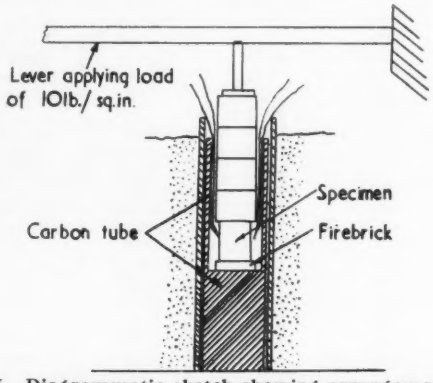

Fig. 6—Diagrammatic sketch showing arrangement of ore test-piece in refractoriness-under-load furnace

II—ADHERENCE OF THE BURDEN TO THE STACK LINING

Starting from first principles, it seems desirable to find out whether scaffolding may not simply be due to the softening of the burden and subsequent adherence of the sticky mass to the firebrick lining.

(*a*) SOFTENING CHARACTERISTICS OF IRON ORES

As a first step in this part of the investigation a series of test-pieces was made up from crushed and graded ore, using the following approximate grading (B.S.I. sieves) :

¼ in.–7-mesh	50%
Through 7-mesh	50%

These test-pieces were moulded in the form of 2-in. dia. cylinders of approximately 200-g. weight, using an A.F.A. rammer. A 10% solution of dextrine and water was used as a temporary bond, and the specimens were dried at 100–105° C. for 24 hr. before testing. One such test-piece was then placed on a fireclay brick supported in a refractoriness-under-load furnace (Fig. 6), the usual silicon carbide blocks being employed for the rest of the thrust column. The specimen was surrounded by a carbon tube to ensure a reducing atmosphere at temperature. The test-piece was heated-up at 10° C./min. under a load of 10 lb./sq. in., and the deformation was magnified 10

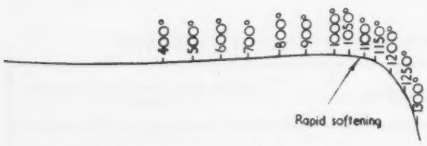

Fig. 7—Deformation graph of Wabana ore heated at 10° C./min. under a load of 10 lb./sq. in.

times and recorded continuously. The results obtained are given in Table VI, and Fig. 7 shows the type of curve obtained.

It will be seen that all the materials examined started to soften at relatively low temperatures. Raw ores soften less rapidly than sinter, as might be expected, since the softening of the sinter is that of the "prefired bond" whilst the raw ores form liquid on heating-up, which liquid will change continuously in composition and viscosity as the temperature is raised.

The Northants ore (siliceous bond) softens at a lower temperature than Frodingham ore (limey bond).

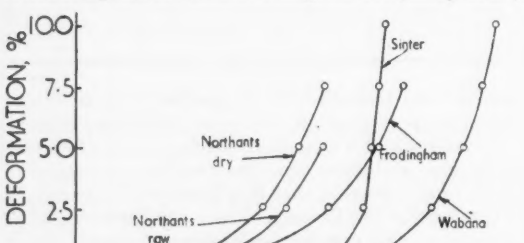

Fig. 8—Deformation of iron ores under a load of 10 lb./sq. in.

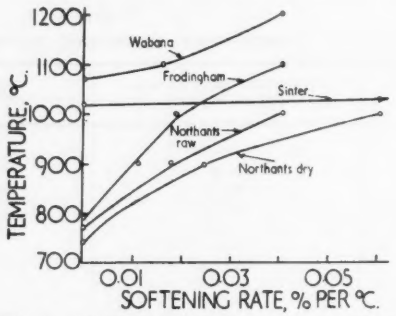

Fig. 9—Softening rates of iron ores under a load of 10 lb./sq. in.

The relatively pure Wabana ore softens at a higher temperature than Northants or Frodingham, but when it softens it deforms more rapidly. Incidentally, X-ray examination of the Northants and Wabana samples after test showed FeO and fayalite in the case of Northants, and Fe_3O_4 and fayalite for the Wabana ore. This shows that the test conditions were reducing and incidentally confirms the higher reducibility of the Northants material.

A further series of tests was carried out at a later date, using a similar technique and including specimens similar to the Appleby burden. These had the grading given on page 29, but were of the following composition :

Frodingham ore	30 parts
Raw Northants ore	10 parts
Dry Northants ore	10 parts
Sinter	20 parts
Coke	25 parts

The temperatures of rapid softening ($2\frac{1}{2}$, 5, and 10% deformation) for the various specimens are included in Table VI, and typical deformation curves for five raw materials plotted against temperature are shown in Fig. 8. As the heating rate was standardized, the rate-of-softening curves could be drawn from Fig. 8 simply by drawing the tangent to the curves at various temperatures. The type of curve obtained for the various raw materials is shown in Fig. 9.

Table VI

DEFORMATION OF IRON ORES UNDER A LOAD OF 10 LB./SQ. IN.

Specimen	Rapid Softening, °C.	Deformation, °C.			
		$2\frac{1}{2}$%	5%	$7\frac{1}{2}$%	10%
Frodingham	790	1020	1100	1140	Failed
Frodingham	840	1080	1120	Failed	Failed
Northants raw	760	960	1030	Failed	Failed
Northants raw	750	950	1010	Failed	Failed
Northants dry	740	910	970	1010	Failed
Wabana	1050	1190	1240	1270	1290
Frod. + 40% North.	770	1010	1090	...	...
Frod. + 60% North.	770	990	1070	1110	...
Sinter	1020	1080	1090	1100	1110
Sinter	1010	1050	1060	1070	1080
Frod. + 40% sinter	780	1010	1070	1090	1110
North. + 40% sinter	750	930	1010	1060	Failed
60% Frod. + 20% North. + 20% sinter ...	750	950	1030	Failed	Failed
40% Frod. + 40% North. + 20% sinter ...	770	970	1040	1070	Failed
20% Frod. + 60% North. + 20% sinter ...	740	900	1000	Failed	Failed
Burden*	750	990	1025	1040	1050
Burden*	750	1020	1050	1070	1080
Roxby *S*	760	990	1070	1100	Failed
Roxby *Q*	820	1090	1140	1160	1180
Glebe	720	940	1010	1060	1090

* Calculated from *Special Report No. 30, The Iron and Steel Institute* 1944

Several duplicates were included and in general good agreement was obtained, provided that furnace conditions were satisfactory and the rate of heating was closely controlled. Small variations must, however, be expected, owing to the heterogeneity of the raw materials. X-ray examination of the samples after the test showed the following phases :

Wabana Ore

Fe_3O_4	Medium/large
$2FeO . SiO_2$	Small/medium
Fe	Very small
FeO	Possible trace

Raw Northants Ore

FeO	Medium/large
Fe_3O_4	Small
Fe	Very small/trace
$2FeO . SiO_2$	Possible trace

The effect of blending Northants ore, Frodingham ore, and sinter is shown in Fig. 10. In general, the softening curve for the blended material lies between the curves of the constituent ores, as is shown by the results for 40% Frodingham, 40% Northants, 20% sinter and for " burden."

It is interesting to note the effect of sinter in an iron-ore blend. With an addition of 40% to Frodingham, for example, no apparent change is noted until the sinter itself begins to soften, after which the rapid deformation associated with sinter softening takes place and the curve for the blended material tends to approximate to that of sinter rather than, as initially, to that of Frodingham ore.

Examination of the specimens (the majority of which had experienced about 7½% deformation) after testing showed a slightly sintered appearance on the surface, but there was no sticking either to the silicon carbide column or the firebrick block. Where more than 10% deformation occurred the extra liquid formed caused sticking to the firebrick.

(*b*) ADHESION TO REFRACTORIES

The work on the sticking of the ores to refractories was continued by tests on three specific types having the following approximate mineralogical constituents :

	Roxby *S*,%	Roxby *Q*,%	Glebe,%
Calcite ($CaCO_3$) ...	55	20	...
Limonite ($Fe_2O_3 . H_2O$)	35	35	...
Chamosite (3(Fe,Mg)O. $Al_2O_3 . 2SiO_2 . nH_2O$)	2–4	25	55
Siderite ($FeCO_3$) ...	6–8	20	45

The technique employed in testing was similar to that already described, while the results obtained are given in Table VI, from which it will be seen that the softening points are again quite low.

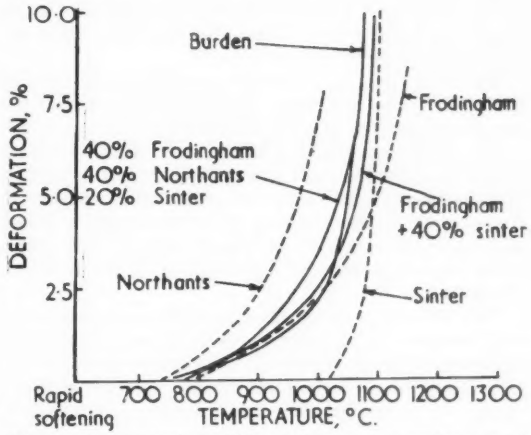

Fig. 10—Deformation of blended iron ores under a load of 10 lb./sq. in.

For the " sticking " tests approximately 100-g. samples of Roxby, Glebe, and sinter were prepared as for the softening tests, except that the test-pieces were only 1 in. high. The specimens were placed on a block of refractory (fireclay, sillimanite, magnesite, or carbon) and heated-up in a Hirsch furnace at 10° C./min. to the melting points of the ores, which were as follows :

Roxby *Q*	1300° C.
Glebe	1250° C.
Sinter	1150° C.

A reducing atmosphere was maintained during the test by resting the refractory block on a bed of carbon and surrounding it with a carbon tube. After cooling, the specimens were examined to assess the amount of sticking to the refractory block. The results of visual observation are given in Table VII.

(*c*) DISCUSSION OF RESULTS

The results obtained on the softening of the three types of ore are very similar to those given in the general investigation of Appleby-Frodingham ores. The Frodingham ironstones represented by Roxby *S* and Roxby *Q* soften over a range of temperatures which can be represented approximately by the following averages :

Rapid softening	790° C.
5% deformation	1100° C.
7½% deformation	1130° C.

Table VII
ADHESION OF IRON ORES TO REFRACTORIES

Ore	Temp., ° C.	Fireclay	Sillimanite	Magnesite	Carbon
Roxby *Q*	1200	Sticking	...	...	No sticking
	1250	Sticking	...	...	No sticking
	1300	Sticking; commencing to slag brick	Sticking; slight drainage into brick	Sticking	No sticking
Glebe	1200	Slight sticking	No sticking	Slight sticking	No sticking
	1250	Sticking; commencing to slag brick	Sticking	Sticking	No sticking
Sinter	1100	Sticking	No sticking	Slight sticking	No sticking
	1150	Sticking; commencing to slag brick	Sticking	Sticking	No sticking

The difference between the various samples is no doubt due to variations in the amounts of the different mineralogical constituents present.

The Glebe iron ore, which is essentially siderite and chamosite, has softening characteristics similar to the Northants ore previously tested.

The most interesting result in the "sticking" tests is the complete lack of any adhesion to the carbon block, although both ores and sinter stuck readily to firebrick even after heating to a temperature below that at which complete melting of the ore took place. Once this stage was reached slagging of the firebrick occurred.

The difference between sillimanite and magnesite with respect to adhesion is small, though sillimanite appeared slightly superior. The results lead to the conclusion that carbon might be a possible stack refractory, provided that oxidation could be avoided.

(*d*) THE EFFECT OF SALT ADDITIONS ON SCAFFOLD MATERIAL

Use of common salt, soda ash, or caustic soda for flushing-out the blast-furnace has been made at various times, with differing degrees of success; for instance, No. 9 furnace at Appleby-Frodingham was treated for 24 hr. weekly with a salt addition equivalent to 20 lb. in each separate charge (26,000 lb. of ore plus 9000 lb. of coke), with a view to minimizing scaffold formation. The mechanism of the action of salt is not clear, and it seemed therefore desirable to investigate the effect of this substance on scaffold material.

(i) Experimental

As complete chemical analyses were available on samples taken from No. 1 furnace at Frodingham, these samples were used for the preliminary work. The analyses and the constitution determined by X-ray examination have already been given earlier in this paper.

To investigate the effect of salt on the melting points of the samples, the material was ground to pass a 72-mesh B.S.I. sieve and was moulded into test-cones with additions of 0, 5, and 10% of sodium chloride. The cones were then heated-up at 10° C./min. in a Hirsch furnace in an atmosphere containing carbon monoxide, and the melting points determined. The results are given in Table VIII, together with the essential parts of the chemical analyses and the constitution.

In order to determine the change in constitution owing to the salt addition, several samples were made up with a 10% salt addition and heated to a temperature 100° C. below their melting points. The resultant mixtures were subjected to X-ray examination. The X-ray photographs were extremely complicated, and, in view of the fact that standards do not exist for many of the compounds which may be formed, much more fundamental work would be necessary to elucidate the structures obtained. There was an indication, however, of a constituent of the potassium chloride type, the replaced sodium presumably entering the alkali alumino-silicate complex. This would be in keeping with the more electropositive character of the potassium ion.

Discussion of Results—It was previously pointed out that the scaffold proper could be broadly divided into two main zones, namely:

(1) An outer (*i.e.*, towards the furnace casing) carbon-deposition zone rich in potassium alumino-silicates.

(2) An inner zone consisting of a fused, or partially fused, agglomeration of slag, coke, iron oxides, and reduced iron, with smaller amounts of potassium alumino-silicates.

It will be seen from Table VIII that the outer zones have higher melting points than the inner zones. This would be expected, as the outer zones approach the composition of $K_2O \cdot Al_2O_3 \cdot 2SiO_2$, which has a melting point of about 1700° C., whilst the inner zones contain appreciable amounts of CaO and FeO, which would be expected to form lower-melting-point eutectics. In all cases the addition of sodium chloride has caused a decrease in the melting point.

There are no published data on certain of the relevant systems, but a certain amount of data is available[4] on melting points in the alkali–Al_2O_3–SiO_2 systems which seems to be relevant to the attack of alkalis on alumino-silicate brickwork. These data are reproduced in Figs. 11 and 12. It will be seen that potash forms much more refractory reaction products than soda. If sections on these diagrams are drawn from a normal brick composition (*X* on the diagrams) to the alkali corner, the course of the reaction between the alkali and the brickwork can be followed. This is shown in Fig. 13, from which it is again clear that much more fluid reaction products will be formed from attack by soda than by potash.

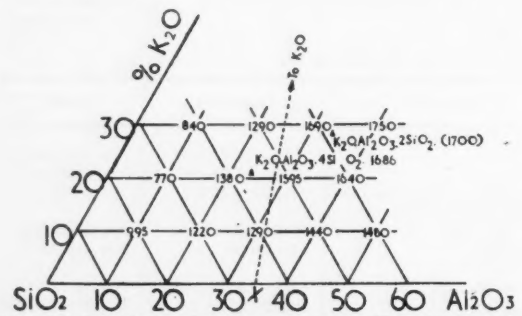

Fig. 11—Melting points in the system K_2O–Al_2O_3–SiO_2 (Clews, Richardson, and Green)

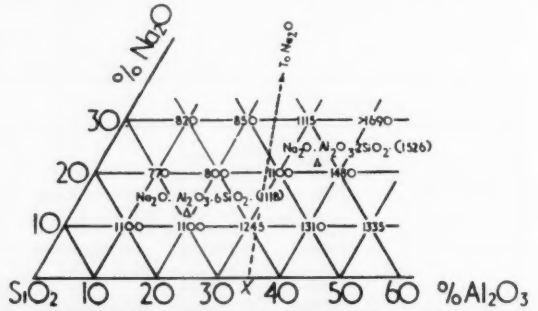

Fig. 12—Melting points in the system Na_2O–Al_2O_3–SiO_2 (Clews, Richardson, and Green)

Table VIII

INFLUENCE OF SALT ON MELTING POINT OF SCAFFOLD MATERIAL

Sample	Chemical Analysis									X-Ray Examination (phases in amount)	Melting Point, °C.		
	SiO_2, %	Al_2O_3, %	Fe_2O_3, %	FeO, %	Metallic Fe, %	CaO, %	MgO, %	K_2O, %	Na_2O, %	CO_2, %	Free Carbon, %		No addition	5% NaCl	10% NaCl
Carbon-deposition zone ..	32·1	23·7	Total Fe as FeO 6·8			Nil	0·8	20·3	1·1	Nil	5·8	Selected portions: (i) Carbon, large (ii) Kalsilite, very large (iii) Kalsilite, med. Unknown, med.	980	960	..
Dense hygroscopic zone ..	34·7	22·1	0·43	2·30	..	2·0	0·7	30·6		..	3·3	Kaliophilite, med./large Unknown, med.	1525	1400	1325
Green zone	30·4	22·4	Total iron as FeO 1·6			Nil	0·6	24·3	2·4	4·2	6·0	Kalsilite, med./large Unknown, med.	1550	1525	1470
Slag-mass cap	15·0	9·2	Nil	18·3	12·9	11·4	2·7	13·3	0·7	2·9	5·7	(i) Unknown phases, poorly crystalline (ii) Iron, med./large Perowskite type, small/med. Unknown, small/med.	1180	1160	1080
Grey heterogeneous zone (outer)	8·4	4·7	0·1	21·8	5·5	14·6	1·8	15·3		..	19·4	Iron, small Unknown, large	1175	1070	1030
Grey slag zone..	9·9	6·3	0·1	21·3	15·7	16·5	2·1	15·1		.	1·25	Iron, med. Unknown phases, poorly crystalline	1230	1170	1120
Working face of scab (opposite scaffold)	Not determined											Kaliophilite, very large	1460	1380	1320

The hump on the potash curve, with a maximum at about 20% of K_2O, is due to the reaction passing the field of stability of $K_2O \cdot Al_2O_3 \cdot 4SiO_2$ (leucite), which has a melting point of 1686° C. It is significant that this compound was detected on the surface of the brickwork from No. 5 furnace after about 5 months' operation, since this suggests that the reaction does,

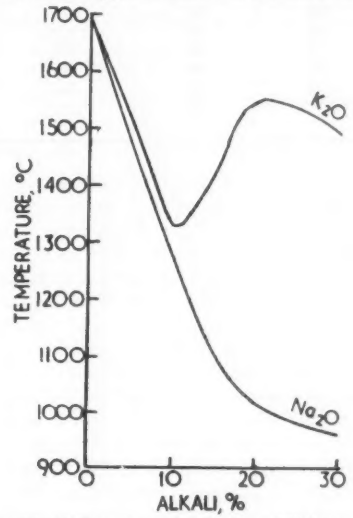

Fig. 13—Influence of alkali additions on the melting point of fireclay brick

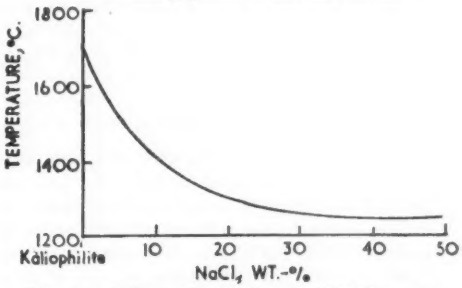

Fig. 14—Effect of additions of NaCl on the melting point of kaliophilite

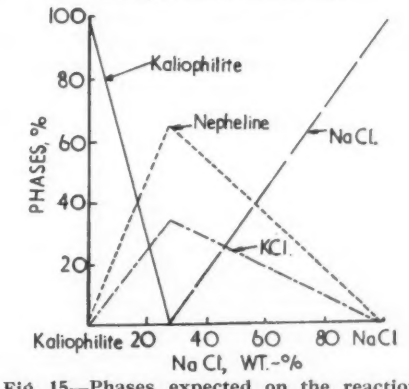

Fig. 15—Phases expected on the reaction of NaCl and kaliophilite

Table IX
REACTIONS BETWEEN KALIOPHILITE AND SODIUM CHLORIDE

Weight, %		Kaliophilite Remaining	NaCl Remaining	KCl Formed	Nepheline Formed	Other Phases
Kaliophilite	NaCl					
100	0	vl	...	...	...	Possible leucite + K_2CO_3
95	5	vl	vs	...	...	Leucite (possibly) vs,
90	10	l	vs/s	vs	...	Leucite, s
85	15	m/l	m/s	s	s	...
80	20	Trace	vs	vs	vl	Traces
75	25	Nil	vs	Trace	vl	Leucite, vs
70	30	Nil	s/sm	s/sm	l	Leucite, vs
60	40	Nil	sm	Nil	l	Leucite, vs
50	50	Nil	m	sm	ml	...

l = large amount; m = medium amount; s = small amount

in fact, proceed along the lines already indicated. It is also worth noting that there is no known sodium analogue of the $K_2O \cdot Al_2O_3 \cdot 4SiO_2$ composition.

It is not possible, because of the lack of data on the phase relations in all the systems concerned, to determine the exact effect of sodium-salt additions on scaffolds containing appreciable quantities of potassium salts, but it does appear on the basis of the effect of common-salt additions on potash recovery that replacement of potassium by sodium occurs, and it would be expected that much more fluid reaction products result on the addition of sodium. Thus it would be anticipated from Fig. 13 that in a potassium aluminium silicate containing 20% of K_2O, the complete replacement of the potassium by sodium would reduce the melting point from 1550° to 1010° C. It is clear, however, that much more fundamental information is necessary before a complete explanation of the effect of salt additions on scaffolds is available.

In order to obtain background information, melting-point and X-ray studies were made of mixtures of common salt and kaliophilite, $K_2O \cdot Al_2O_3 \cdot 2SiO_2$.

(ii) Preparation of Kaliophilite and Salt Mixtures

The compound kaliophilite was prepared by repeated sintering of potassium carbonate and ignited china clay at temperatures initially below the melting point of the carbonate and gradually increased to 1500° C. X-ray examination of a slowly cooled sample showed it to be at least 90% kaliophilite, the remainder being leucite ($K_2O \cdot Al_2O_3 \cdot 4SiO_2$,) and unaltered potassium carbonate. Various mixtures of this material and common salt (NaCl) were prepared and the melting points determined in the high-temperature microscope, with the following results:

Material		Melting Point, °C.
95% kaliophilite and	5% NaCl	1510
90% ,, ,,	10% ,,	1410
85% ,, ,,	15% ,,	1360
80% ,, ,,	20% ,,	1300
75% ,, ,,	25% ,,	1280
70% ,, ,,	30% ,,	1260
60% ,, ,,	40% ,,	1260
50% ,, ,,	50% ,,	1250
Kaliophilite ($K_2O \cdot Al_2O_3 \cdot 2SiO_2$)		1700*
Nepheline ($Na_2O \cdot Al_2O_3 \cdot 2SiO_2$)		1530*
Potassium chloride (KCl)		770
Sodium chloride (NaCl)		800

* As given by Clews, Richardson, and Green (reference 4).

A small sample of each mix was then sintered for some time at 50° C. below the determined melting point and slowly cooled to give a sample for X-ray examination. The constitutional analysis is given in Table IX.

Discussion of Results—In Fig. 14 the effect of the salt addition to kaliophilite is clearly shown as rapidly lowering the melting point from 1700° to 1260° C. at 30% addition, after which, up to 50%, there is no further change.

As the K^+ ion is of a more electropositive character than the Na^+ ion, it is to be expected that there will be a tendency towards the formation of potassium chloride (melting point 770° C.) on the reaction of sodium chloride and $K_2O \cdot Al_2O_3 \cdot 2SiO_2$, with the formation of soda alumino-silicate according to a reaction of the type:

$$\underset{\text{(kaliophilite)}}{K_2O \cdot Al_2O_3 \cdot 2SiO_2} + 2NaCl = \underset{\text{(nepheline, melting point 1530° C.).}}{Na_2O \cdot Al_2O_3 \cdot 2SiO_2} + 2KCl$$

Although this is a very general representation—there presumably being numerous side reactions—it is interesting to note that the X-ray results offer some confirmation. Assuming this reaction, the theoretical constitutions have been calculated, and these are shown in Fig. 15. It will be seen that the experimental data bear quite a similarity to the calculated phases, *viz.*, the gradual disappearance of kaliophilite with the formation of nepheline and potassium chloride. At the higher concentrations of sodium chloride there is no kaliophilite, and the proportions of nepheline and potassium chloride are reduced because of the dilution effect of the excess sodium chloride. It seems likely that some sodium chloride and/or potassium chloride is lost by volatilization.

In practice it has been found that salt treatment of a blast-furnace scaffold has helped to remove the scab and has led to increased potash recovery in the slag and flue dust.

CHOICE OF REFRACTORIES TO MINIMIZE SCAFFOLDING

It is obvious from the preceding matter that:

(*a*) Even high-grade iron ores soften at comparatively low temperatures.

(*b*) All such ores adhere to fireclay bricks at quite low temperatures.

Carbon bricks show no such adhesion and should

therefore offer possibilities for stack linings, provided that they do not show disruption owing to carbon deposition and do not burn. A considerable amount of work has been carried out on the effect of carbon monoxide on carbon bricks, both as normally manufactured and with additions of iron and iron oxide. The results of this work have been reported elsewhere by Howie and Mackenzie.[5] In the initial tests the rapid method for testing fireclay bricks was employed and it was shown that carbon bricks produced considerable amounts of carbon dioxide, suggesting that carbon deposition was occurring. It has, however, been shown that this is in part due to the test procedure, the carbon dioxide being formed at least in part by the action of the carbon on water vapour carried over with the carbon monoxide used. If metallic iron is present in the brick, carbon deposition does take place and disintegration can occur. With the commercial brands of bricks, however, neither carbon deposition nor disintegration was found in tests of up to 100 hr. duration. More detailed information as to the amount of reaction which can be expected can be obtained from Tables I and II of Howie and Mackenzie's paper.

The next problem, *i.e.*, whether the bricks are liable to burn, is even more problematical. Very little free oxygen should be present in the stack region, but there is always the possibility of attack by carbon dioxide and consequent solution of carbon as CO. Certain tests have been made with a view to evaluating this risk, the procedure being as follows.

A weighed cylinder ($1\frac{1}{4}$ in. × $\frac{1}{2}$-in. dia.) of carbon brick or coke was heated up to 700° C. in an atmosphere of nitrogen and then to 1000°, 1100°, or 1200° C. in the test gas. The maximum temperature was maintained for 5 hr., the specimen then being cooled to 700° C. and then to room temperature in nitrogen. It was later removed for examination and reweighing. The gases used were as follows, the rate of flow being maintained at 5 litres per hour :

(1) Pure carbon dioxide.
(2) 75% CO + 25% CO_2.
(3) 60% N_2 + 30% CO + 10% CO_2 (synthetic blast-furnace gas).

Several composite tests were carried out to compare the reactivities of carbon brick and coke under similar conditions. Test-pieces ($1\frac{1}{4} \times \frac{1}{4} \times \frac{1}{2}$ in.) of carbon brick and coke were placed side by side in a gas stream, or alternatively $\frac{1}{2}$-in. cubes of carbon brick and coke were placed in line in a gas stream, both with the carbon brick ahead of the coke and *vice versa*. In both tests the appearance and loss in weight of the carbon brick and coke were recorded. The percentage and actual losses in weight of the carbon-brick and coke specimens in these tests are given in Table X and shown graphically in Figs. 16 and 17 respectively.

Table X

LOSS IN WEIGHT (GRAMMES × 100) OF SPECIMENS TESTED IN VARIOUS GASES

The figures in brackets denote percentage loss in weight

Temp., °C.	CO_2		75% CO + 25% CO_2		Synthetic Blast-Furnace Gas	
	Coke	Carbon Brick	Coke	Carbon Brick	Coke	Carbon Brick
1000	351 (44·2)	320 (37·9)	54 (6·7)	76 (6·4)	31 (3·5)	26 (2·6)
1100	402 (70·0)	447 (52·7)	100 (14·8)	101 (10·9)	40 (4·6)	33 (3·3)
1200	425 (82·4)	Burnt	150 (24·8)	154 (19·9)	45 (5·9)	42 (4·3)
	Coke and Carbon Brick Side by Side					
1000	57 (21·8)	150 (34·8)	13 (5·5)	44 (12·7)	...	...
1100	150 (65·0)	262 (70·0)	34 (15·3)	87 (23·8)	...	...
1200	Burnt	Burnt	Slightly burnt	Burnt	...	...
	Coke and Carbon Brick in Line—Coke in Front					
1000	75 (33·0)	177 (48·0)	10 (5·1)	37 (10·0)	...	...
	Coke and Carbon Brick in Line—Carbon Brick in Front					
1000	56 (24·0)	133 (43·6)	14 (5·7)	35 (10·5)	...	...

Discussion of Results

The reaction $CO_2 + C \rightarrow 2CO$ should proceed more rapidly as the temperature is increased above the equilibrium point (approximately 700° C.). This was borne out by the results obtained, and indeed, after 5 hr. at 1200° C., both the carbon brick and the coke were almost completely oxidized by pure carbon dioxide. The introduction of carbon monoxide into

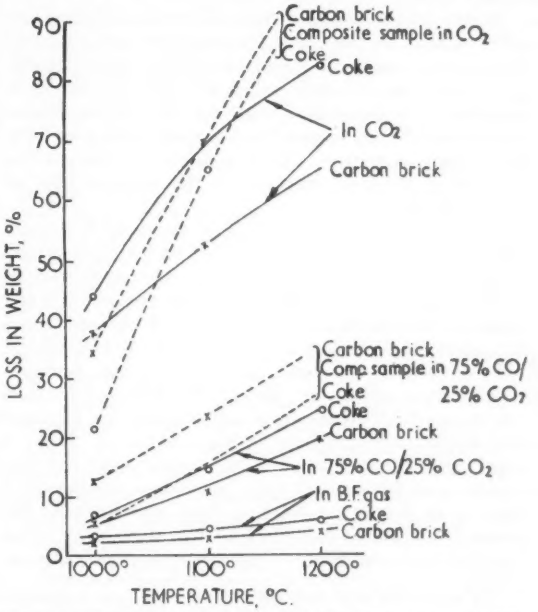

Fig. 16—Percentage loss in weight of specimens tested in various gases

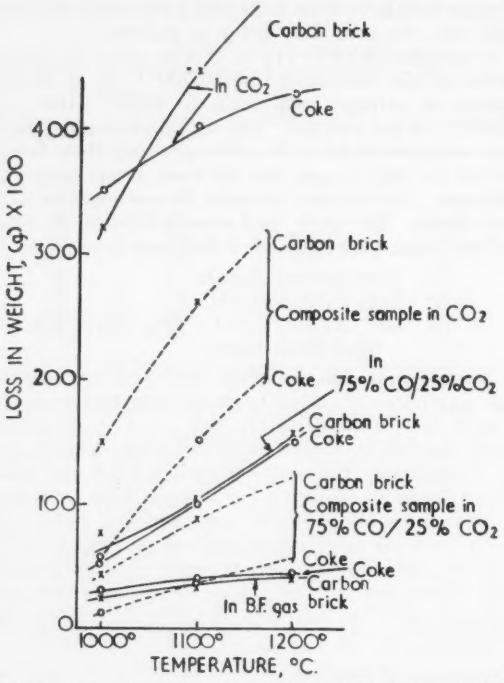

Fig. 17—Loss in weight (g. × 100) of specimens tested in various gases

the gas stream reduces the rate of burning, as does also the introduction of a diluent, such as nitrogen. The data given in Fig. 16 rather suggest that the coke is more reactive than the carbon brick, but the "in-line" tests showed a slightly higher loss for the carbon brick.

In Fig. 17 the actual weight of carbon oxidized has been plotted against the temperature and suggests that carbon bricks do tend to oxidize more rapidly than coke, but the differences are quite small. It is interesting to note that whereas the carbon bricks on oxidizing went to powder, the coke tended to keep its original structure. This is doubtless due to the additional grinding involved in the manufacture of carbon bricks.

It is unlikely that there will be appreciable carbon dioxide in that part of the stack which falls in the temperature range 1000–1200° C. The main constituents, namely carbon monoxide and nitrogen, will not promote combustion, and the trial of carbon bricks in a stack lining therefore appears to be worth while.*

Even before this work was carried out, arrangements were made by Mr. G. D. Elliot for trials of odd carbon bricks in a stack lining in furnaces at Appleby-Frodingham. The risks of such a trial are obvious, but the results both of the works and laboratory tests proved so encouraging that a 15-ft. carbon-brick section was built in the central portion of the stack of No. 9 furnace. This furnace has now been in operation for over a year, and, so far, no trouble has been reported. Some oxidation may have occurred, but it has certainly not been of a particularly serious order. Since scaffolding does not normally become a problem until a furnace has been in operation for about a year, it is too early to state whether the use of carbon bricks in the stack will provide a complete answer to the scaffold problem.

* Those who still feel that such trials are dangerous may be encouraged by the fact that scaffolds themselves contain a great deal of carbonaceous material that has not burnt away.

CONCLUSIONS

Examination of a number of blast-furnace scaffolds and of scaffold-forming materials in the laboratory have led to the following preliminary conclusions :

(1) All iron ores soften at comparatively low temperatures, the lowest values being obtained with the low-grade ores.

(2) All iron ores adhere to fireclay bricks after heating to temperatures below the melting point of the ore.

(3) Both fireclay bricks and the alumino-silicate material in the burden are attacked by alkalis (in particular potash), with the formation of potassium aluminium silicates, some of which have very low melting points. This doubtless assists both adhesion of burden to the firebrick lining, by providing a sticky surface, and consolidation of the burden to form a scaffold. The carbon deposition in the lining tends to displace the latter inwards, forming a shelf, which provides an anchor for any scaffold-forming material. In the later stages of scaffold formation this brickwork is forced further out into the furnace, forming a "spine" in the middle of the scaffold.

(4) No adherence occurs between iron ore and carbon brick when the two are heated in contact and cooled to room temperature.

(5) Carbon bricks burn fairly rapidly at 1000–1200° C. in carbon dioxide, but the burning falls off rapidly with a drop in temperature or the introduction of carbon monoxide or nitrogen.

In view of these conclusions the trial of carbon bricks in the central portion of blast-furnace stacks is considered worth while, although improved preparation and distribution of the burden may ultimately render such precautions unnecessary.

Acknowledgments

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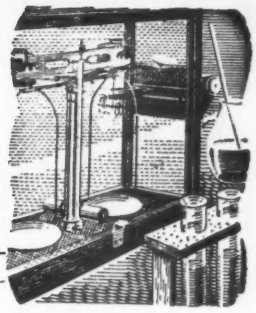

Locomotives for Iron and Steel Works

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SYNOPSIS

The duties and costs of operation of steam locomotives in iron and steel works are analysed, and it is shown that the savings made possible by the use of other types of locomotives are closely dependent on a suitable choice or rearrangement of their traffic duties so as to take advantage of their greater availability. Costs at existing works prove that there is greater scope for saving in the layout of track and the design of rolling stock for such purposes as ingot cars and tipping slag ladles than by the use of alternative types of locomotive. The savings possible by the use of conveyors for bulk-handling duties are estimated and are shown to be very considerable provided the work of at least one locomotive is thereby replaced. Diesel locomotives cannot be so readily overloaded as steam locomotives, and locomotives of higher nominal power would be required for the heavier steelworks duties. The maintenance of Diesel locomotives is discussed and proposals are put forward for two or three standard types.

INTRODUCTION

To form a correct technical judgment as to the most economical type of locomotive for a particular duty it is necessary first of all to have clearly in mind the nature of the duty and the tractive effort and power required to carry it out at sufficient speed. In the case of a works employing a number of locomotives for a variety of duties it would, however, be more costly in the end to have a special locomotive precisely suited to each duty, and a broad review of the duties of the locomotives as a whole, leading to their classification, is also necessary. Such a review may show that some duties do not make economical use of any locomotive of a generally useful standard type, and it is then possible to consider whether the duty can be modified or whether it can be more economically carried out by other means. Finally, since it is impossible to determine the economy with which any duty is being carried out without a knowledge of the total cost, or to suggest with any confidence ways of improving it without knowing how the total cost is made up, it is necessary to ascertain such costs, to divide them up between the principal items of expenditure, and to relate them in some way to the work done for that expenditure.

The question of the most suitable type of locomotive for iron and steel works can scarcely be separated, therefore, from a broad consideration of the handling of materials in such works, and a study of the influence on the total cost exercised by factors such as track and plant layout, maximum output of the plant, rolling-stock design, and facilities for repair. The first approach to this problem was therefore made by a study of the operation of locomotives and other material handling plant at a number of representative steelworks and from a broad point of view. To illustrate the importance of this wide angle of approach it may be mentioned that the opinion is widely held by those with long experience of the industry that steam locomotives alone are capable of giving reliable service in the extremely severe conditions peculiar to such works. There is no doubt that the conditions in which steam locomotives work in the average steelworks today are more severe than in any other field of use, and certainly more so than in railway shunting yards. Taking a narrow view one might accept this as a basic fact and the matter would resolve itself largely into a question as to whether any type of internal-combustion locomotive could be built strong enough to do the work without losing all the advantage of higher fuel efficiency in excessive costs of maintenance. It is suggested, however, that to obtain an ultimate reduction of the high cost of moving material in a steelworks it is equally important to improve the conditions of the locomotives' duties, especially at a time like the present, when extensive new plants are to be laid down.

The first part of this report is devoted to a study of the duties and costs of operation of locomotives in iron and steel works. In this section the possible savings to be secured by the use of alternative types of locomotives are also considered, and it will be seen that these savings may be closely dependent on a suitable rearrangement of the traffic duties to take

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advantage of the greater availability of internal-combustion locomotives.

In the second part of the report consideration is given to the economies made possible by transferring certain bulk-handling duties to conveyors or other types of material-handling plant, as is already being done in some modern plants. Attention is also directed to the great savings which can be effected by ensuring that locomotive power is not wasted in overcoming avoidable resistance. This not only increases the useful haulage capacity of the locomotives, but also reduces wear and tear, and is a matter which ought always to be given the closest attention before attempting to secure the advantages of locomotives of higher efficiency. It will be seen that other types of locomotives than the steam locomotive will not give good service if they are regularly overloaded, and that locomotives of considerably greater nominal power will generally be required to perform the heavier types of duty satisfactorily. As in the larger sizes the capital cost of such locomotives per horse-power is greater than that of the steam locomotive, the overriding importance of ensuring that the power is used effectively will be obvious.

The final section of the report deals with the technical features of various types of locomotive available for iron-and-steel-works use. Information is given which should afford a clear idea of what is involved in the maintenance of Diesel locomotives, and the requirements that must be satisfied to ensure the minimum maintenance costs with locomotives of this type. The classification of the duties of locomotives in the first part of the report is linked up in this final section with the characteristics of the various types, and suggestions are made not only as to the duties for which various types are most suited, but also as to possible standard locomotives to cover the great majority of the duties in an iron and steel works. There is no doubt that a reduction of capital cost could be obtained, especially in the case of Diesel locomotives, by common agreement in the industry on two or three standard specifications, and the report provides data and puts forward suggestions which might provide a useful starting point for consideration as to whether such specifications could be prepared and agreed upon. Certain duties of a special nature are separately considered as being suitable for steam-accumulator or electric locomotives, or even capstan winches.

PART I—THE DUTIES AND COSTS OF OPERATION OF LOCOMOTIVES IN STEELWORKS

DUTIES OF LOCOMOTIVES IN IRON AND STEEL WORKS

The transport duties at an iron and steel works may be broadly classified as follows :

(i) Supply of raw materials
(ii) Removal and disposal of slag
(iii) Transport of hot metal
(iv) Transport of ingots and moulds
(v) Delivery of finished products
(vi) Transport of maintenance materials, general stores, etc.

Most of these duties involve two distinct operations ; the setting or marshalling of individual trucks or ladles, and the haulage of complete trains of vehicles to and from the various sections of the plant, the main-line-railway sidings, waterside docks or wharves, and the mines and slag tips, over distances which may vary from a few hundred yards to several miles.

It is the general practice in iron and steel works to allocate locomotives primarily to particular duties, but to maintain a traffic control system with foremen stationed at various points who may order any locomotive to carry out other movements or to assist on another duty. The method of allocating duties is very similar in most works, and it is usual to find that setting and marshalling operations are carried out by locomotives working locally, and the longer hauls are made by other locomotives often specially selected for these duties according to their power or state of repair.

This division of the work into shunting and long hauls corresponds to normal railway work, but many of the movements of complete trains though short in distance are exceptionally arduous in character. There are two reasons for this : first, that it is common practice to raise raw materials in bulk by locomotive, through considerable differences of level, to the top of the blast-furnace storage bunkers or to the open-hearth-furnace stage ; second, that loaded ingot cars, and slag and hot-metal ladles are not only extremely heavy vehicles but are frequently badly lubricated owing to the heat of their contents and to spillage.

Table I shows broadly the division of the duties in a " normal " steelworks with a weekly output of 10,000 tons. The word normal is emphasized, for every actual plant has its abnormal features which

Table I

TYPICAL ALLOCATION OF LOCOMOTIVE DUTIES IN AN IRON AND STEEL WORKS

Note: The allocation is drawn up for a hypothetical works of conventional type having a single group of blast-furnaces and a total steel output of 10,000 tons/week.

Duty	Number of Locos.
Blast-Furnaces:	
Front side (setting ladles, etc.)	1
Ore and other materials to bunkers	1
Hot metal to steel plant	1
Slag removal to tip	1
Steel Plant:	
Feed materials, including lime and scrap preparation	3
Pitside (ingots and moulds to soaking pits, etc.)	2
Slag removal	1
Coke-Ovens and By-Products	1
Sinter Plant	1
Mills	2
Inwards and Outwards Traffic (main line and wharves)	3
Miscellaneous Duties	2
Standby Locomotives (in steam)	1
Total	20

generally increase the work to be done, and the Table does not apply, unless by chance, to any existing works.

The great majority of these duties will be three-shift duties, so that in addition to the twenty locomotives allocated, one or more will be undergoing boiler washing-out and light repairs, apart from those in the shops for heavy repairs. The duties designated only by sections of the plant (*e.g.*, " Mills ") are purely shunting operations in and around the department named. " Inwards and Outwards Traffic," however, includes both shunting at the main-line sidings and wharves and the haulage of trains to and from the various sections of the plant.

ANALYSIS OF TOTAL TONNAGE OF TRAFFIC HANDLED

Owing to the difficulty of estimating the work done in shunting operations in terms of ton-miles, it is the common practice of railway companies as well as steel firms to base all shunting locomotive costs on the locomotive service hour. This is reasonable if there is no variable factor in the working condition other than that arising from the type of locomotive used. Railway shunting yards, for instance, do not usually present widely differing conditions one from another.

This is not the case in iron and steel works. Conditions differ greatly in different works, and the cost per service hour may be as much a reflection of the works layout, for instance, as of the efficiency of the locomotive. Moreover, some adverse factors in a works layout, such as track bottlenecks which restrict the loads that can be taken to less than the capacity of the locomotive, have the effect of lowering the cost per locomotive-hour because they limit the work that can be done by each locomotive, and so lead, on this basis, to an entirely false impression of efficiency of operation of the locomotives. In order then, to have a sound basis for assessing the value of alternative types of locomotive as a means of reducing costs, and of the relative importance of other factors in this respect, it is essential to have some measure of the useful work done by the locomotives.

The difficulty of estimating the total ton-miles, however, in the multifarious operations of a steelworks railway system is obvious. It would involve an enormous amount of detailed calculation, and in the end would be no true measure of the work done because of the prevalence of steep gradients and the wide variation in the rolling resistance of steelworks rolling stock. To base costs on output of steel would be completely misleading, if only because of the different starting point of the process at different works. It is, however, not so difficult, as at first sight appears, to estimate the total tonnage of traffic handled in a steelworks per hour, and some firms actually keep a record of this figure. Generally speaking, amongst self-contained works the greater the total tonnage the greater the average distance of haul, but as greater space usually affords a better track layout, the effect of the extra distance is usually counterbalanced by fewer movements of each vehicle. As will be seen later, the influence of mileage is not discernible in the actual costs obtained from a number of works of different character, whereas the effect of other features is very marked.

The total tonnage of traffic handled appears, therefore, to be a reasonable and by far the most practical basis for ascertaining the true costs of locomotive operation in a steelworks as a whole, and the remarkable consistency of the actual costs obtained from various works on this basis is considered to be good evidence of the correctness of this. It can only be used as an overall measure, of course, and cannot be applied to individual duties.

In estimating the total tonnage, a particular quantity of material is counted once only between each stage in the process of manufacture, even though it may be handled in several movements by different locomotives. The only exception to this is when material in excess is put to storage for a period and withdrawn at a later date. Thus, the total weight of iron passing through the plant will appear first as ore supplied to the blast-furnaces. It will then be counted as hot metal transferred to the steel plant or as pig iron for dispatch. The weight of iron in the hot metal will then be counted again as part of the weight of steel ingots transferred to the soaking pits. If any portions of the steel products are transferred by rail from one mill to another for successive stages of rolling, the amount of iron they contain will appear once again in the total tonnage of traffic, and finally it will appear in the finished products delivered by works locomotive to the main-line sidings for dispatch. In this way the total tonnage of traffic will amount to between five and twelve times the total steel output, or even more where appreciable quantities of ore are transported from local mines. Where the mines traffic is extensive, however, it is generally advisable to assess the costs separately from those of the works traffic proper, as the conditions usually differ considerably, particularly in respect of the distances covered and the number of shifts worked. Empty vehicles in no case count as tonnage, but the weight of moulds is added in this analysis to the weight of the ingots when car casting is the practice. (Further reference is made to this point on p. 46.)

Although the composition of the total traffic will vary considerably between different works, it is desirable to have some idea of how it is made up before considering the effect of particular duties on the costs of locomotive operation. Taking the case of a works with blast-furnaces, steel plant, and rolling mills, it is assumed that all of the ore is delivered to the plant by ship or rail and is moved by works locomotive to the blast-furnaces, either at high or low level. It is also assumed that coal for the coke-ovens is delivered by the railway company to a point whence the wagons run by gravity to the tippler for discharge on to the conveyor, as this arrangement is generally aimed at in siting the coke-ovens in a modern plant. The total tonnage of traffic for such a works might work out approximately as in the first of the two columns of figures in Table II, on a percentage basis.

The second column of figures in Table II gives the percentage of locomotive-hours allocated roughly to each item of traffic. This is based on the allocation shown in Table I, but the duties of some of the locomotives have been divided, as they would be in practice, to give a closer approximation in the case

Table II

EXAMPLE OF COMPOSITION OF TOTAL TRAFFIC AND CORRESPONDING TOTAL LOCOMOTIVE-HOURS

Item of Traffic	Total Tonnage, %	Loco-Hours, %
Coke-ovens (by-products plant)	4	5
Sinter plant	4	5
Blast-furnace feed materials (except coke)	21	15
Blast-furnace slag	9	8
Hot metal	10	6
Steel-plant cold materials ...	7	15
Steel-plant slag	2	3
Ingots and moulds	22	10
Mills	13	15
Debris and rubbish	2	3
Bricks, stores, miscellaneous ...	6	10
Standby locomotives	—	5
Total	100	100

of the smaller items of traffic. Both these columns of percentages can only be interpreted in the broadest sense as they are bound to vary greatly from one works to another, but they are useful as giving a general indication of the effect of the conditions associated with any particular item of traffic on the costs and conditions of locomotive operation as a whole. On comparing the two columns of figures, the differences between them will be seen to be in accordance with what one would expect from the nature of each duty, and attention will later be directed to some considerations arising from these differences.

EFFECT OF VARIOUS FACTORS ON TONNAGE HANDLED PER HOUR AND OVERALL COST

Table II shows that the tonnage handled per hour varies according to the duty, but nearly as great a variation occurs between the overall tonnage handled per hour at various works, and the factors responsible for this variation must therefore be taken into account in any study of locomotive costs.

This variation, as between five works at which the costs of locomotive operation were studied, is shown in Table III. The principal factors causing this wide variation are indicated in the Table, but some additional details may be given. Works A is an old-established plant in which the restrictions of the site are such that all incoming raw material, outgoing finished products, and slag, have to reverse their direction of travel over short and awkward dead ends of track which severely limit the number of vehicles that can be taken at a time and give rise to a good deal of waiting about. The locomotives used are consequently of relatively small size and power, and their hourly cost is the lowest of those ascertained. But, as will be seen from the Table, the reduction of hourly cost is far from sufficient to balance the inefficient utilization due to bad track layout.

At Works B a higher proportion of the total locomotive-hours are spent in miscellaneous shunting duties because of the absence of blast-furnaces with their concentrated ore, hot metal, and slag haulage. The principal reason for the low hourly cost of the locomotives at Works C, as compared with Works D, is the fact that most of the locomotives are operated with two men only ; at Works E two shunters are attached to every locomotive in addition to the driver.

The overall locomotive costs are analysed and considered in detail in a later paragraph, but taking them as they stand in Table III, they show how great an influence factors outside the type of locomotive employed have on the real cost of locomotive haulage. Clearly, to reduce the cost of handling material in a steelworks to the minimum possible, it is necessary to pay at least as much attention to works and track layout and rolling-stock design, as to the locomotives themselves, and these matters will be considered in more detail in Part II of this report.

The ultimate measure of the cost of locomotive haulage must, of course, be expressed as some proportion of the total cost of manufacturing a ton of finished steel products. This, however, cannot be done on a truly comparative basis unless all handling operations, including those performed by conveyors, hoists, wagon tipplers, cranes, and by hand, and the cost of maintaining permanent way are included ;

Table III

TRAFFIC HANDLED PER LOCOMOTIVE-HOUR AND OVERALL COST AT VARIOUS WORKS

Works	Approx. Output from Blast-Furnaces and Steel Plant, tons/week	Traffic Handled per Locomotive-Hour, tons	Overall Cost		Features of Works	Other Factors
			Per Locomotive-Hour	Per Ton of Traffic		
A	6500	16·1	14*s.*	9·9*d.*	Old works; very poor track layout	...
B	8000	24·4	16*s.* 7*d.*	8·3*d.*	No blast-furnaces	...
C	20,000	28·7	15*s.*	6·3*d.*	Old works diffused into small units	2 men only for most locos.
D	21,000	31·3	18*s.* 5*d.*	7·2*d.*	Modern works, long average distances	Roller bearings on some cars
E	20,000	40·8	19*s.* 9*d.*	5·7*d.*	Modern works, short average distances	Roller bearings extensively used

such costs would have to cover either the whole process of manufacture, including the mining and transport of ore, or well-defined stages of manufacture. It is hardly necessary to mention this in a report of this nature, but the question of the effect on locomotive costs, as well as on the overall handling costs, of transferring certain duties from railways to conveyors or other mechanisms, or of alterations in the process itself affecting haulage requirements, cannot be neglected, particularly in view of the increasing use of conveyors for the supply of ore, etc., to blast-furnace bunkers.

Suppose, for instance, all the blast-furnace feed materials were handled by conveyors or electric transporters of one kind or another, and that all ingots were cast in pits and handled electrically to the soaking pits, just as they are at present from the soaking pits to the mills. Other things being equal that would of itself reduce the tonnage per locomotive-hour by 25%, as may be seen by adding the relevant figures in Table II. But if the conveyors and other electrical equipment were more economical than locomotives, the overall cost of handling per ton would be less. It will be seen, therefore, that when using the cost per ton of traffic as a criterion of locomotive operation at various works, care must be taken that the overall nature of the duties is comparable, and in no circumstances can this criterion be indiscriminately applied to individual duties within a works, as a glance at Table II shows.

The most economical means of carrying out any duty must obviously be determined primarily by the relative cost of alternative methods as applied to that particular duty, but the question of using alternative methods for the bulk handling of feed materials to blast-furnaces and steel plant has an important bearing on the overall costs of locomotive operation, since these duties generally involve steep gradients and, as will be seen later, may require locomotives of greater power and therefore higher capital cost than would otherwise be necessary. It is also the heaviest duties which are responsible for the greatest share of the costs of maintenance.

ANALYSIS OF LOCOMOTIVE COSTS

It has already been mentioned that the practice as regards the number of shunters employed per locomotive varies between different works. Other factors making up the total locomotive cost also vary considerably, as will be seen from Table IV.

Through the courtesy of the Chief Mechanical Engineer of the L.M.S. Railway, corresponding costs for shunting locomotives in main-line railway service are added both for steam locomotives and for the Diesel-electric locomotives extensively used by the L.M.S. Railway in their shunting yards. This Table does not include figures for interest and depreciation which are essential for the purpose of estimating any ultimate saving to be obtained from the use of Diesel locomotives because many of the steam locomotives at present in use in steelworks are underpowered for the duties they have to perform and would have to be replaced by considerably more powerful Diesel locomotives. The figures for interest and depreciation for the main-line railway locomotives are : steam, 1*s*. 1*d*. ; Diesel-electric, 2*s*. 8*d*. ; bringing the respective totals up to 19*s*. 2*d*. and 12*s*. 10*d*. (These figures are based on an estimated life of 30 years for both types, but the rate of interest may differ from that customarily assumed in such calculations in the iron and steel industry.)

It is clear from Table IV that the saving obtained by the main-line railway cannot be expected merely by a simple substitution of Diesel locomotives of similar type in a steelworks. In the first place, wages would not be appreciably affected in most steelworks. The great variation in this item between different works suggests that savings in wages could in some cases be obtained by removing obstacles to vision, improving track layout, etc., and examination of other factors necessitating the employment of two shunters in addition to the driver on the majority of the locomotives. It is the case, however, that where traffic conditions generally are best, permitting the use of more powerful locomotives and the haulage of trains of maximum length, the wages cost is highest, simply because the amount of work for the shunters attached to each locomotive is correspondingly greater. The main-line-railway wages figure, on the other hand, includes no shunting charges. The saving in favour of the steam locomotive is simply on account of the fireman which all main-line steam locomotives carry by rule. He takes little or no part in the shunting and is dispensed with on the Diesel locomotive. In steelworks, on the other hand, the shunters do little or no firing except when the

Table IV

ANALYSIS OF HOURLY OPERATIONAL COSTS OF SHUNTING LOCOMOTIVES IN STEELWORKS AND ON MAIN-LINE RAILWAYS

Item	Iron and Steel Works (Steam)			Main-Line Railway	
	Highest	Lowest	Average	Steam	Diesel-Electric
Wages	10*s*. 6*d*.	6*s*. 8*d*.	8*s*. 10*d*.	7*s*. 10*d*.	4*s*. 6*d*.
Coal (or fuel oil)	4*s*. 8*d*.	2*s*. 8*d*.	3*s*. 10*d*.	5*s*. 5*d*.	1*s*. 8*d*.
Water	7*d*.	2*d*.	3*d*.	2*d*.	...
Maintenance Services and Stores ...	5*s*. 4*d*.	2*s*. 8*d*.	3*s*. 8*d*.	4*s*. 8*d*.	4*s*. 1*d*.
Total*	19*s*. 5*d*.	14*s*. 0*d*.	17*s*. 6*d*.	18*s*. 1*d*.	10*s*. 3*d*.

* The highest, lowest, and average totals at actual works are given, not the sums of the respective individual items

Table V

ESTIMATED COMPARATIVE HOURLY COSTS OF STEAM AND DIESEL LOCOMOTIVES IN STEELWORKS SERVICE

Item	Steam	Diesel-Electric	Diesel-Mechanical
Wages	8*s*. 10*d*.	8*s*. 10*d*.	8*s*. 10*d*.
Fuel	4*s*. 4*d*.	1*s*. 7*d*.	1*s*. 6*d*.
Water	3*d*.	...	...
Maintenance, services, etc.	3*s*. 8*d*.	4*s*. 1*d*.	4*s*. 1*d*.
Interest and depreciation	1*s*. 1*d*.	2*s*. 8*d*.	1*s*. 10*d*.
Total	18*s*. 2*d*.	17*s*. 2*d*.	16*s*. 3*d*.

locomotive is at the coaling stage, and would be equally necessary if Diesel locomotives were employed.

The slightly lower average coal cost in steelworks as compared with the main-line railway may be discounted. It arises from the small size and light duties of the locomotives in Works A and B, in Table III. On the other hand, the lower cost of maintenance, services, and stores is of some significance. In the case of the main-line steam locomotives nearly 60% of this cost is attributable to services, whereas only 30% is so accounted for in the case of the Diesel-electric, the actual cost of repairs being slightly higher for the Diesel than for the steam. The percentage cost of services for steam locomotives in steelworks is much lower than on main-line railways, running-shed equipment, etc., being of the simplest ; and it is improbable that much saving could be effected on this account by the introduction of Diesel locomotives. Indeed, as will be seen in Part II of this report, there is considerable scope for lowering the cost of maintenance of steelworks steam locomotives. If Diesel locomotives of no greater power were substituted for steam locomotives on some of the existing duties of the latter, the cost of maintaining them would probably be far greater than the figure shown in Tables IV and V.

If the comparative figures for the hourly running costs of the L.M.S. locomotives are modified in respect of wages and services, so as to make them applicable to steelworks practice, the result is as shown in Table V.

A third column has been added to Table V to cover the case of Diesel locomotives with mechanical transmission for the lighter duties. The capital cost of such locomotives would be approximately midway between that of the corresponding steam and Diesel-electric locomotives. A slight additional allowance has been made in the fuel cost on account of the higher efficiency of mechanical transmission. It will be clear from these figures and the foregoing considerations that the estimated saving in favour of Diesel locomotives on an hourly basis is scarcely decisive. The matter therefore hinges very largely on the question as to how much extra tonnage per hour can be handled by Diesel locomotives. This will be discussed in the final section of the report when other factors affecting the question have been considered.

PART II—FACTORS AFFECTING THE USEFUL POWER AND MAINTENANCE COSTS OF LOCOMOTIVES

INFLUENCE OF PARTICULAR DUTIES ON CAPITAL AND RUNNING COSTS

Of the various duties shown in Table I to which locomotives are allocated in iron and steel works, some require greater power than others. Broadly, the haulage of complete trains of material in bulk, such as ore, hot metal, slag, ingots, and scrap to the steel furnaces, may require the full power of the locomotives, whilst the setting and marshalling of individual vehicles is usually well within their capacity. Taking the allocation set out in Table I, it may be said that roughly half the locomotive duties require the full power of the locomotive. By this is meant that on such duties the locomotive is loaded with the maximum number of vehicles it can take at a time. The actual number or weight will vary greatly according to the gradients to be surmounted, the type of rolling stock, etc. ; matters which will be discussed later in this section.

For the moment, attention is directed to the fact that these bulk-handling duties settle to a large extent the size and, therefore, the capital cost of the locomotives, since it is impracticable to confine particular locomotives entirely to particular duties, and they also are responsible for the greater part of the wear and tear. On the other hand they represent a higher factor of usage of the locomotive in the sense of tons handled per locomotive-hour ; and for the same underlying reasons they are the duties which most readily lend themselves to other methods such as conveyor systems.

It has already been pointed out that the transfer of an appreciable proportion of these duties to conveyors or other handling systems would have the effect of lowering the overall tonnage handled per locomotive-hour by the remaining locomotives, but on the other hand, it might permit a reduction in the power and cost of the locomotives used, and it would certainly result in a reduction of their maintenance cost. Marshalling duties, by their very nature, must be carried out by locomotives of some kind, and since the effect of relieving the locomotives of bulk-handling duties would be to lower the cost of their operation on marshalling work, it is all the more pertinent to examine the possibilities of doing this.

The bulk-handling duties may be classified as follows :

(i) The supply of ore and other feed materials to blast-furnace bunkers
(ii) The supply of scrap and other feed materials to steel plants
(iii) The transfer of hot metal from blast-furnaces to steel plants
(iv) The transfer of ingots and moulds from the casting bay to the stripping bay
(v) The removal and disposal of slag

These, in short, are the duties which account for the greater part of the cost of locomotive operation in the normal iron and steel works. It will be seen that in addition to the full loading of the locomotive, all these duties except the transfer of hot metal involve

other severe conditions. The supply of feed materials to blast-furnaces and steel plants generally involves lifting them through a considerable difference of level. As will be seen when the effect of gradients is discussed, the steam locomotives at present employed on these duties are generally underpowered and they have to be thrashed to surmount the gradients. The same applies to slag-bank work. Slag removal is also responsible for heavy wear and tear because spillage over bearings often makes it difficult to start the ladle carriages. The same applies to an even greater extent in the case of ingot cars, and damage is often caused to locomotive tube plates through the structural stresses set up when endeavouring to start such trains by shock. Slag tipping also subjects locomotives to great structural shocks when carried out by the common chain method.

These severe conditions naturally affect the cost of maintenance of steam locomotives in steelworks and reduce still further the margin of possible gain by the use of Diesel locomotives. Indeed, if they were to be accepted as inevitable, Diesel locomotives of practicable or economic size would be unlikely to give satisfactory service under such conditions. These conditions can, however, be mitigated and in many cases eliminated. The position in the past has been that consideration has been paid primarily to the requirements of the process, and the space and capital expenditure devoted to traffic have been minimized, full advantage being taken of the ability of the steam locomotive to withstand continuous overloading and to go on working even when the moving parts have worn to the last degree of slackness. It is important to realize that even the steam locomotive cannot give its most reliable and cheapest service under such conditions.

POSSIBILITY OF USING CONVEYORS FOR CERTAIN DUTIES

Of the bulk-handling duties classified above, the supply of ore and other feed materials to blast-furnace bunkers provides at present the main possibility of using conveyors. Conveyors are already largely used for the supply of coke from the coke-ovens, and also in many cases for the supply of ore. In the case of coke the conveyor takes the material from the point of manufacture and usually deposits it in the storage bunker, thus eliminating altogether the use of locomotives. Where this can be done a clear basis for comparison between the costs of handling by the different methods is presented.

The position with ore is more complicated, as it is generally necessary to deposit the ore in several bunkers according to grade. Where no ore-grading plant exists and the material is taken into the plant by rail at a point some distance from the blast-furnace, it would be a natural procedure to move the already loaded trucks by locomotive to a point near the blast-furnace before elevating the material to the bunkers. If a conveyor is used for elevating the ore it would generally have to discharge at the top into an electric car for distribution to the bunkers.

A further complication arises from the fact that other materials besides ore have to be supplied to the blast-furnaces, some of which, such as hot sinter, may present difficulties in handling by a belt. If any of these are to be handled by locomotive the capital cost of the conveyor plant cannot be set off against the cost of constructing a ramp for the ascent of the locomotive to the blast-furnace gantry. One way of meeting this difficulty is to use an electric wagon hoist which can elevate hopper wagons loaded with any material to the gantry level, where it can be arranged that they run by gravity over the bunkers and thence to ground level. This, however, involves the construction of a descending ramp, though it may be steep and further curtailed in length by including one or more reversals of direction. It also has the serious disadvantage of restricted capacity since only one wagon can be lifted at a time.

Table VI

COST OF MAINTENANCE AND ESTIMATED POWER COST OF TWO CONVEYOR SYSTEMS*

Note: These costs are based on the figures for 1946. The costs for individual years for maintenance may vary by 35% above or below the average, due mainly to renewals of belting. Power consumption remains substantially constant.

	Battersea Power Station	Deptford Power Station
Number of conveyor belts ...	16	17
Capacity of individual belts, tons/hr.	240/480	150/300
Width of individual belts, in. ...	30/40	24/36
Mean belt speed, ft./min. ...	383	359
Total lift of system, ft. ...	224	226
Total length of system, ft. ...	3140	2600
Total tonnage handled per annum	800,000	800,000
Maintenance cost per ton, pence	0·53	0·66
Estimated power cost per ton (at ½*d.* per unit), pence ...	0·052	0·034

RUNNING AND CAPITAL COSTS OF CONVEYOR INSTALLATIONS

It will be apparent, therefore, that no universally applicable comparison of costs as between locomotive haulage and conveyor systems can be made. In order, however, to draw such broad conclusions as are possible some typical conveyor costs have been ascertained. Data were made available, through the courtesy of one of the large steel firms, of the capital costs of a number of conveyors it is proposed to instal for ore handling in connection with extensions to their plant, and the Engineer-in-Chief of the London Power Company kindly supplied particulars of the maintenance costs and other details relating to the large coal conveyors at Battersea and at Deptford Power Stations, which are of the same order of capacity as those used in steelworks. It is difficult to give single figures for length, lift, etc., of a conveyor system of any complexity, as the material may follow one of several paths. The figures tabulated in Table VI will, however, give a measure of the extent of the conveyor systems concerned and the total tonnage handled is computed on the same basis as that used for estimating locomotive-hauled traffic ; that is to

* The data for Table VI were kindly supplied by the London Power Co., Ltd.

say it comprises the total intake of coal plus any double handling to and from local storage. The total lift of the system is the difference of level between the lowest point of intake and the highest point of discharge, and in computing the total length, belts which run in parallel alongside each other are counted as one path only.

The mean tonnage handled per hour works out at 91·4 in both cases, but all the conveyors are not continuously in operation. By expressing the cost in terms of tonnage handled, however, a basis of comparison is obtained, and it is apparent that so far as cost of maintenance and power are concerned a conveyor system gives an immense saving as compared with locomotive haulage. Taking the best overall locomotive cost per ton of traffic in Table III, and reducing the figures in the ratio of 15/21 (Table II) to relate them to blast-furnace feed materials, of the total running cost of 4·1*d.* per ton of traffic hauled, 1·1*d.* represents the cost of maintenance, 0·9*d.* the cost of fuel (power), and 2·1*d.* the wages cost. The average length of haul may be greater in the case of blast-furnaces, but the lift will generally be less, and it appears to be safe to say that the running costs of a conveyor system would be less than a quarter of the running costs of locomotives to do the same duty.

It is more difficult to draw any general conclusions on capital charges. Where a set of conveyors is completely isolated from buildings the cost of supporting steelwork towers and foundations may be twice as great as the cost of the conveyor belt and mechanism itself. In order to obtain some comparative idea of the magnitude of the capital charges the case may, however, be considered of an extensive conveyor system it is proposed to instal at a large iron and steel works to handle ore and limestone in connection with a new ore-grading plant ; a portion of the prepared iron ore and limestone will be handled between the grading plant and the blast-furnace gantry, whilst the remainder will be loaded into wagons for transport to other works. The particulars given in Table VII for this installation show that it is of even greater magnitude than the extensive installations at the London power stations.

In calculating the interest and depreciation a life of thirty years has been assumed for locomotives of both steam and Diesel types, and the rate of interest is taken at 6%. The conveyor-maintenance costs already set out include routine replacements of belts and moving parts. The cost given in Table VII does not include any extra structural work in buildings other than the special supporting towers and conveyor structure, but on the other hand no account is taken in this comparison of the cost of the permanent way on which the locomotives would have to run.

The total tonnage per hour to be handled by the conveyor system is expected to be 312 tons. Taking again the most favourable figure in Table III, and multiplying the number of tons per locomotive-hour by the ratio of 21/15 to give a figure appropriate to blast-furnace feed materials, five steam locomotives would be required to perform this duty. In view of the limited distance over which some of the locomotives would have to work (this point is referred to below) this estimate may be on the high side, but if the five locomotives are assumed, in accordance with the ratio generally prevailing in steelworks, to include one spare locomotive, the comparison should be valid. If the capital cost of five 16-in. steam locomotives is taken at the moderate figure of £25,000, the interest and depreciation per ton of traffic (assuming they work continuously) works out at 0·205*d.* on a 30-year basis, taking the same rate of interest (6%) as in calculating the figure of 1·05*d.* per ton (Table VII) for the conveyor.

It will be seen that the extra capital charges to be debited against the conveyor are very far from making up the difference in operating costs. Even if we take a figure for maintenance and power well in excess of either of those given in Table VI, say 0·75*d.* per ton, the total cost per ton of moving the material by conveyor becomes 1·8*d.*, whereas the total cost by locomotive is 4·3*d.*

There is one consideration that will go some way to closing this large gap in costs when the quantities of material to be handled are not so great. The basis of calculation, namely, a ton of traffic, while suitable for the purpose of a general survey of locomotive costs, may be misleading when applied to particular duties. Suppose, for instance, we consider the simple case of the movement of ore directly from a wharf to the blast-furnace bunkers. If a conveyor is substituted only for the lift from ground level to gantry level, locomotives are still required to move the ore the greater part of the distance. Moreover, an additional transfer car is required to distribute the ore from the point of discharge at gantry level to the various bunkers. The decisive question in such a case is to what extent the installation of the conveyor will reduce the number or size of locomotives necessary to carry out the movements at ground level.

It will be apparent, without going into figures, that where relatively small quantities have to be moved, such as could comfortably be handled by one locomotive, no appreciable reduction of locomotive time could be effected and the only items to set off against the conveyor would be the cost of the ramp and a certain length of permanent way, together with some reduction of the fuel and maintenance costs of the locomotive. It is believed, however, that the quantity below which a conveyor would show no saving in iron-and-steel-works practice may be considerably smaller than is often supposed. In the first place a simple conveyor such as we have imagined would cost

Table VII

PARTICULARS AND CAPITAL COST OF A LARGE CONVEYOR SYSTEM FOR AN ORE PLANT

Number of conveyor belts	15
Capacity of individual belts, tons/hr....	5 at 70–140 8 at 600 2 at 450
Width of individual belts, in. ...	24–54
Mean belt speed, ft./min.	260
Total length of system, ft.	3718
Total tonnage handled per annum ...	2,730,000
Cost of conveyor belts	£50,710
Cost of supporting towers	£64,500
Cost of electrical equipment	£12,570
Interest and depreciation per ton ...	1·05*d.*

something of the order of one-tenth of the elaborate systems represented in Tables VI and VII. Secondly, the existing locomotives are generally grossly overloaded on such duties as blast-furnace or other inclined-ramp work, and the extent to which this contributes to the total cost of operating the locomotives is not easy to ascertain. The matter comes fully to light, however, if the question of substituting Diesel locomotives for these duties is considered, for it is essential, with locomotives of this type, that they should be of adequate power if they are to give reliable service. This will be considered in detail in the following section.

EFFECT OF GRADIENTS ON LOCOMOTIVE POWER REQUIRED

To bring this point into focus, Fig. 1 has been prepared to show the horse-power required to haul trains of various weights up gradients of varying steepness at a constant speed of 6 m.p.h. A rolling resistance of 15 lb./ton has been assumed.

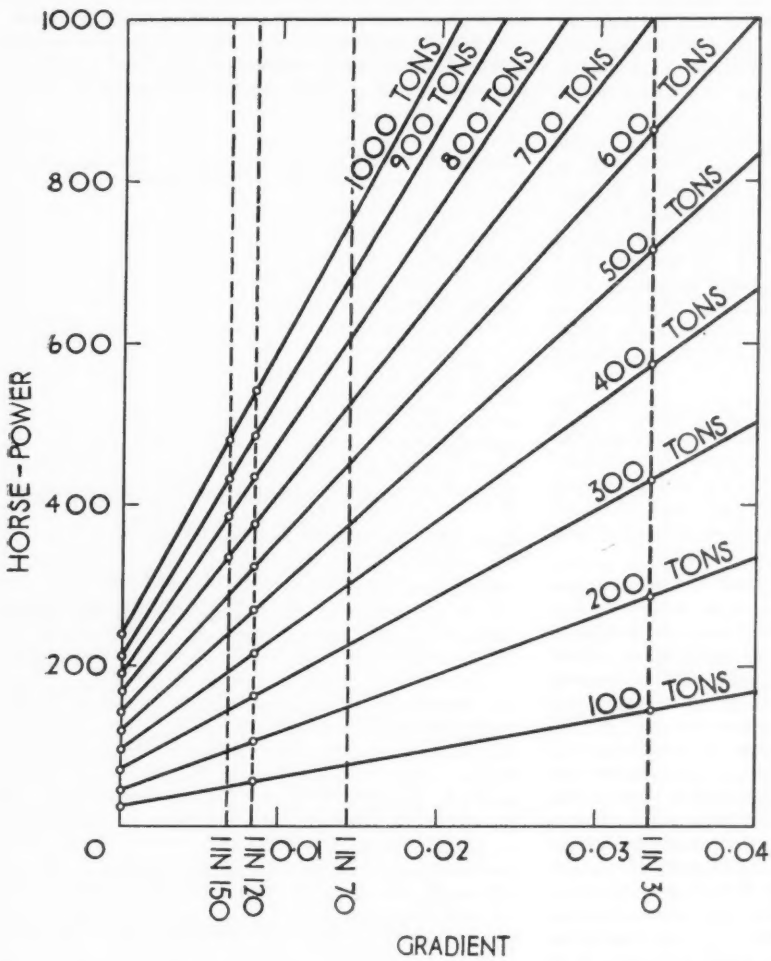


Fig. 1—Power required to haul various gross train loads at a steady speed of 6 m.p.h. up various gradients; rolling resistance, 15 lb./ton

A typical steam locomotive, as used in steelworks, having a boiler pressure of 170 lb./sq. in., two 16 × 24-in. cylinders, and 3 ft. 8 in. driving wheels will give a maximum indicated horse-power at 6 m.p.h. of 265, assuming that the locomotive is worked in full gear at a cut-off of 75% and with a full head of steam.* Assuming a mechanical efficiency of 80% this gives a maximum of 212 h.p. at the rim of the driving wheels, available for moving the weight of the train *including* the weight of the locomotive itself, which may amount to 43 tons.

It will be seen from Fig. 1 that whereas such a locomotive could haul at 6 m.p.h. on the level, the heaviest loads it is likely to be able to start (taking into account the increase of rolling resistance at starting), it could not take a net train load of about 100 tons at a steady speed of 6 m.p.h. up a gradient of 1 in 30 or, say, three 20-ton loaded ore hoppers with a tare weight of 12 tons each. Easing the gradient to 1 in 70 would mean that a train of about 210 tons could be taken. In existing works the blast-furnace and steel-furnace stage inclines are frequently as steep as 1 in 30. It would be impossible to maintain production if the loads were restricted to the extent indicated by Fig. 1, and additional weight is taken by gaining as much momentum as possible on the level and rushing the incline. Apart from the dangers of this practice, flogging locomotives of this type, with their comparatively small boilers, up to as high a speed as possible in full gear is wasteful of fuel and greatly accelerates the rate of wear and tear.

The lifting of material in bulk by locomotives thus imposes a very serious limitation on the capacity of a plant unless the power of the locomotives can be greatly increased, for duplication of tracks would usually involve a complete redesign of a major portion

* This is calculated by the method enunciated in the writer's paper on "The Development of Locomotive Power at Speed," *Proceedings of the Institution of Mechanical Engineers*, 1947, vol. 156, p. 404. The fact that shunting locomotives work with saturated steam does not make sufficient difference, at these low speeds and very late cut-offs, to affect these approximate figures.

of the plant, even if the large amount of extra space required were available. In the case of existing works' sites, there are generally difficulties in the way of using locomotives of much larger power and size, particularly on account of track curvature and clearance. Supposing, however, that these can be overcome, the point to which all these considerations are directed is that with plant units of the size now becoming usual, locomotives of much greater capital cost than those at present in use will be essential if all materials are to be fed to a high level by locomotive, and where conveyors can be conveniently used, the financial case in their favour becomes correspondingly stronger.

A good illustration of the extent to which locomotive power is affected is afforded by one of the major new works to be erected in this country. It is actually not a case of blast-furnace supplies, where probably the use of locomotives is already obsolescent as a means of lifting the materials, but the supply of cold materials to a large open-hearth-furnace plant. It has been decided to lift all cold materials, chiefly scrap, to the level of the furnace stage by locomotive. In order to keep pace with the productive capacity of this modern plant it is estimated that trains of 600 tons gross weight must be lifted at a time.

It would obviously be quite impracticable to handle trains of this magnitude on the present type of steep ramp, and an incline of 1 in 70 has been decided upon. Reference to Fig. 1 shows that to haul 600 tons up a grade of 1 in 70 at a steady 6 m.p.h. requires a locomotive of at least 500 h.p., and it is in fact proposed to use large Diesel-electric locomotives of 650 h.p. The capital cost of such locomotives, on a basis comparable with the figure of £5000 for a 16-in. steam locomotive, is about £22,000, or more than four times as great.

Belt-type conveyors could not, of course, be used to handle scrap, and a 16-in. steam locomotive could not take trains of this magnitude up such an incline, but this example of the logical development of existing methods does bring home the real cost of using locomotives to lift materials in bulk as compared with conveyor or similar systems.

Although the problem of the supply of feed materials to melting shops cannot at present be solved by the use of conveyors, it will be realized from the foregoing that the arrangement whereby all materials are lifted to furnace stage level by locomotive must necessarily be a costly one and that in developing new methods of material handling and charging for open-hearth plants, it is worth while having as one aim the elimination of this lift so far as locomotives are concerned. The position is aggravated in cases where the materials are lifted after loading into pans or charging bogies on account of the small net weight of material compared with the weights of the bogies and pans. Reference to Table II will show the very adverse ratio of total tonnage to percentage of locomotive-hours on this duty. The costs of locomotive operation per ton, as given in Table III, have to be multiplied by 15/7 to give the figures appropriate to steel-plant cold materials.

EFFECT OF ROLLING-STOCK DESIGN ON USEFUL WORK OF LOCOMOTIVE AND MAINTENANCE COSTS

Bulk-handling duties which are entirely outside the scope of conveyors are the transfer of hot metal from blast-furnaces to steel plants, and the removal and disposal of slag. They do not involve any lifting, however, other than that resulting from differences of ground level, except in the case of elevated slag banks. The question of slag tipping will be considered separately in a later paragraph.

The movement of ingots and moulds is one of the heaviest duties that the locomotives are required to perform, but the distance involved is generally short and the track level. Consequently, a favourable ratio of tonnage to locomotive-hours is obtained (Table II). If, however, the weight of the moulds were omitted (and it is questionable whether it is logical to include them, since the weight of slag and hot-metal ladles, scrap boxes, etc., is omitted) this ratio would be approximately halved. In plants where the ingots are cast in pits the moulds are not moved on cars. The high ratio of tonnage to hours for this duty cannot therefore be regarded as an indication that it is a favourable one for locomotive haulage, and as it is one which could conceivably be performed by other

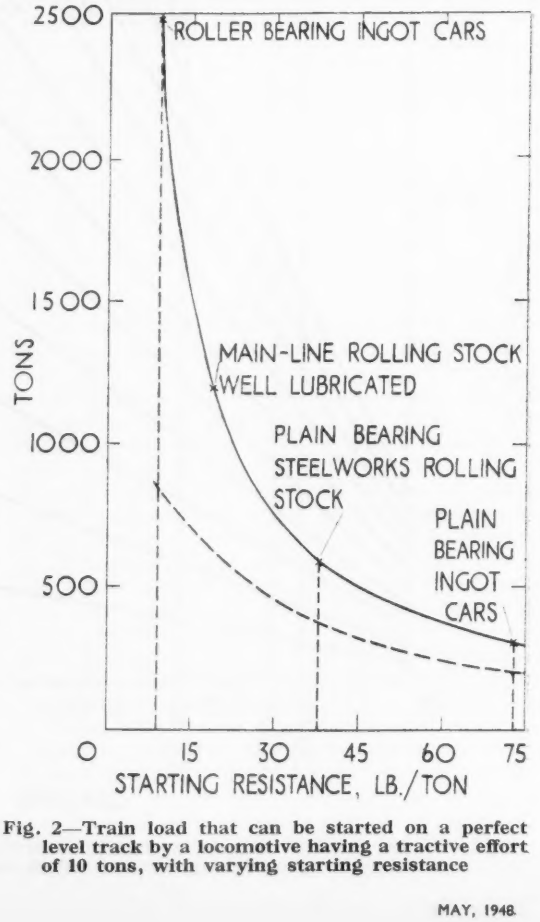


Fig. 2—Train load that can be started on a perfect level track by a locomotive having a tractive effort of 10 tons, with varying starting resistance

methods, close consideration of this duty is warranted.

All the duties mentioned in the above two paragraphs involve the loading of metal or slag in the molten condition, and spillage frequently occurs. The effect of this in the vicinity of ordinary bearings is to destroy the lubricating oil or grease. This occurs while the vehicles are standing and therefore increases their starting resistance, which is in any case always higher than the rolling resistance. Figure 1 shows that on a straight level track a locomotive can move at a low speed the maximum weight of train it is likely to be able to start. In the case of ingot bogies, therefore, the useful capacity of the locomotive is directly related to their starting resistance. This relationship is shown by the curve in Fig. 2, in which the train-load (exclusive of locomotive) that can be started by a locomotive having a tractive effort of 22,400 lb. (10 tons) is plotted against the starting resistance of the rolling stock.

Some actual figures for starting resistance of ingot cars were given by Mr. G. R. Walshaw and Mr. L. Griffiths at the first meeting of The Iron and Steel Engineers Group, on 16th October, 1946,* and these are shown in Fig. 2 (once the train has been got on the move the resistance falls to considerably lower values than those shown in Fig. 2). Such figures, of course, are very variable in practice, depending to some extent on the size and weight of the vehicle, and the adhesion of the locomotive also varies greatly according to the condition of the rails. The rails are usually dry and gritty in the casting bay of a steel plant, so that something like the full tractive effort of the locomotive may be available, but on the other hand the condition of the track is usually bad, due to the frequent lowering or dropping of heavy weights across the rails. Local irregularities in the track will considerably increase the resistance of a train of vehicles and may introduce a gravity factor which will be proportionately greater the lower the frictional resistance. It is impossible to estimate precisely the effect of these factors, but the dotted line in Fig. 2 will be found to be nearer the maximum loads that can be started in practice than the theoretical curve.

In a certain steel plant using ingot cars with plain bearings these are of two types. The smaller cars carry only two ingots whereas the larger cars carry up to six ingots. The direct heat transfer to the bearings has also been reduced somewhat in the larger cars by placing bars between the under side of the bottom plate and the top of the car, so leaving an insulating air layer in between. With the larger cars the locomotive can start a maximum weight of 200 tons (four cars) as against 160 tons (seven cars) with the smaller ones. It will be seen that these weights are near the maximum that can be started. Bearing in mind, however, that the actual resistance may vary considerably above and below the figures given in Fig. 2, it is clear that there will be many occasions when actual difficulty will be experienced in getting the train on the move, and it is not unknown for drivers to take a short run at a train of loaded ingot bogies to start it by shock. These conditions will often be the direct cause of leaking tube plates or other damage necessitating urgent repairs.

At another steel plant, where all the ingot cars are mounted on roller bearings of very satisfactory design, trains of eight bogies carrying four 3-ton ingots each and amounting to 325 tons train weight (excluding locomotive) are the normal load. Such a weight, as is seen from Fig. 2, is well below the maximum that can be started, with the consequence that the locomotives are at all times able to start the ingot trains smoothly and without shock or undue stress on the locomotive frame.

The cost of converting an ingot car from plain bearings to roller bearings is about £300 per car.* A little consideration will show that such an expenditure must bring a handsome return in any steel plant with a weekly output of much over 5000 tons. It is true that the number of locomotive-hours spent on casting bay duties is not necessarily proportional to the weight of the ingot trains, since the locomotives allocated to this task perform a number of other miscellaneous duties such as moving empty moulds for preparation, etc., but it is found in practice that when plain-bearing ingot cars are in use, 5000–6000 tons of steel per week is about the maximum that can be handled by one locomotive dealing with all casting-bay duties. For a modern shop with an output of 10,000 tons two locomotives would be required with plain-bearing cars, whereas at the plant referred to with roller-bearing cars, which has an output of this magnitude, one locomotive deals comfortably with all the casting bay duties. Allowing that the two locomotives may be of smaller size, the difference in capital cost of the locomotives alone would pay for the conversion of some thirteen cars, whilst the saving in running costs at the rate of at least 14*s.* an hour would cover the capital charges arising from the conversion of two or three hundred bogies, more than double the number that would actually be required. Any extra cost of maintenance of the ingot cars will be more than offset by the saving in maintenance costs of the locomotive.

A rough calculation such as this suffices in the case of a large plant, since there is so great a margin in favour of roller bearings. In the case of a smaller shop it might not be quite so easy to show a saving on paper, but it is pertinent to observe that it would be practically essential to have roller-bearing cars if it were proposed to use Diesel locomotives, since the latter cannot so readily withstand the shocks and the abuse involved in setting in motion heavy loads with partially seized bearings. Where new cars have to be bought the extra cost of roller bearings will be appreciably less than the cost of conversion, and it is safe to say today that there is no justification for building new ingot cars with plain bearings.

It is, however, essential that the design of the bearing and particularly the housing, which affords protection against the effects of spillage, shall be adequate. As there have been instances where roller bearings have given disappointing results and have

* *Journal of The Iron and Steel Institute*, 1947, vol. 155, p. 87.

* Figure given by Mr. G. R. Walshaw, Iron and Steel Engineers Group, *loc. cit.*

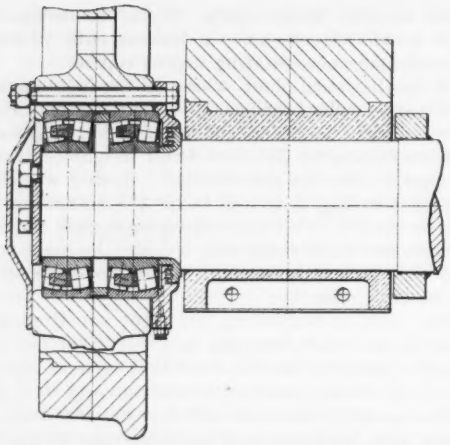


Fig. 3—Spherical roller bearing applied to slag ladle or ingot car. (By kind permission of Skefko Ball Bearing Co., Ltd.)

incurred heavy replacement costs, a drawing of a bearing and housing which have given excellent service in ingot cars is reproduced in Fig. 3, through the courtesy of the Skefko Ball Bearing Co., Ltd.

Some spillage is unavoidable when casting, but there is another practice associated with the use of ingot cars which is so destructive that the writer found it hard to believe at first that it is as widespread as it appears to be. This is the habit of stripper-crane drivers of banging sticking ingots and moulds on the car platforms to loosen them. At one works the condition of the roller bearings with which the ingot cars were equipped is so bad as a result of this practice that practically all their advantage in reduced starting resistance is lost, whilst maintenance costs on the other hand are increased. Where pit casting is in use means have to be provided to loosen sticking ingots, and a particularly neat device in use at one such works, due to Mr. J. F. R. Jones, is illustrated in Fig. 4.

It is understandable that casting on a moving vehicle which can immediately be cleared away from the valuable space in the casting bay has certain advantages in the planning of the process. But here also, as has been shown, the locomotive operating costs involved are very much greater than may be realized, especially when the process angle is so exclusively maintained as to lead to such rank abuse of the rolling stock.

The present tendency is to eliminate the method of casting in pits and to do all casting on cars. It is therefore important that care should be taken that the cars are equipped with bearings of a satisfactory design and that they are not used as stripping blocks. Taking a long-term view, the duty is not one which in itself appears to lend itself ideally to the use of locomotives, and proceeding from the basis that movement by locomotive is at best an expensive way of handling material in bulk in a works, it is open for consideration whether some modern form of pit casting would not effect great savings. The ingots all have to be moved to one place, the stripping bay, which in a new works can be within a matter of yards from the point where they are cast. To move them by locomotive generally involves carrying them several times the actual distance they need to be moved.

The disposal of slag presents similar problems to the ingot traffic, but this is an item of bulk handling of material for which no alternative method is available other than haulage by locomotive. Spillage of slag occurs mainly in steel plants where, however, the quantity is much less than at the blast-furnaces. At one works slag ladles and carriages of the same type are used at both places. They are of the normal Dewhurst type with 7, 8, or 10-ton bowls mounted on oil-lubricated plain bearings. Whereas the locomotives can haul 25 full slag ladles from the sidings adjacent to the blast-furnaces to the tip, giving a gross train weight approaching 500 tons, six is the maximum number that can be taken over the same route from the steel plant. The steel-plant ladles are permanently allocated to the steel plant as part of its equipment, and the difference in number hauled is due to the difference in the condition of the bearings.

This is a somewhat extreme example, but at most works it will be found that a greater number of slag ladles can be taken from the blast-furnaces than from the steel plant, and although this is tolerated because of the relatively small quantity of steelworks slag, it does mean a corresponding wastage of fuel and increase of maintenance. There seems to be no inherent reason why means should not be provided to avoid the spillage of slag at steel plants, at any rate when the ladles are mounted on their cars, and this is one certain way of reducing locomotive costs.

There is a good deal of variation in the size and capacity of slag ladles and carriages at different works, and in view of the magnitude of this traffic, it is

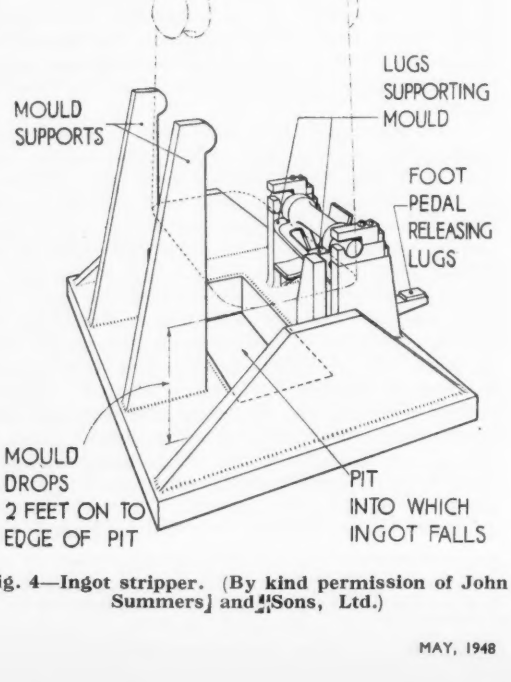


Fig. 4—Ingot stripper. (By kind permission of John Summers and Sons, Ltd.)

Table VIII

COMPARISON OF USEFUL LOAD CAPACITY OF VARYING SIZES OF HOT-METAL CARS

Tare Wt. of Ladle and Car, tons	Capacity, tons	No. of Carrying Wheels	Type of Bearing	No. of Cars Hauled by Locomotive	Gross Wt. of Train, tons	Gross Wt. of Metal, tons	Useful Weight, %
34	25	4	Plain	4	236	100	42
46	35	4	,,	4	324	140	43
60	50	8	Roller	4	440	200	45
85	75	12	,,	3	480	225	47
115	125	12	,,	2	480	250	52

worth paying some attention to the most economic design. The ratio of " pay load " to tare weight has been found to vary between 1/1·4 and 1/2·5 at the works visited. The heaviest vehicles were found at a works with a particularly severely graded route with inclines of 1 in 50 which cannot be taken at speed, whereas the lightest were hauled over a well-aligned route with one dip at 1 in 40, under a bridge, which can be taken by momentum. The result is that whereas the gross weight of the slag trains is three times greater at the latter works, the net weight of slag disposed of per trip is 4½ times as great. It would be more logical to use the lightest possible type of vehicle for the more difficult routes. The matter is bound up to some extent with the method of slag tipping, which is considered below.

As regards the transport of hot metal, this also is a duty which cannot normally be performed by any more suitable means than by locomotives, since the movements of metal are necessarily intermittent, and the quantities to be taken at a time are generally well within the capacity of a single locomotive. As the size of blast-furnaces increases, however, the tendency is to use ladles with larger capacity to take the greater quantity of metal tapped, and these are now usually mounted on double-bogie cars equipped with roller bearings. The smaller types of hot-metal carriages are still in use at many works and Table VIII shows the advantage that is gained in the proportion of useful weight hauled by the employment of larger ladles and carriages. Clearly, however, the ladle cars must not be so large that they may frequently be only partly full, or the advantage will be lost.

Because both slag and hot metal have to be poured from above into the ladles there is a tendency for the track, on which the ladles stand during pouring, to be at a low level. To some extent this is offset by the fact that ladles stand singly or in twos at individual furnaces and are hauled out to the prevailing ground level for assembly into trains. In some older works, however, the gradient is steep and is combined with a curve of short radius. This often results in difficulty in getting the ladles on the move, especially where the cars are mounted on plain bearings and when the rails are wet, and such conditions cause heavy wear and tear of the locomotives. Nothing can further the general objective of reducing locomotive costs better than attention to such points. The internal disposition of each unit of plant must obviously be determined solely by the needs of the process, but its position in relation to other units and the disposition of the railway tracks approaching it should equally clearly be governed by the aim of moving the materials of the process to and from the plant unit with the least expenditure of energy.

SLAG TIPPING

Most of the slag removed from blast-furnaces is tipped to waste. It often happens that the restricted area available has caused the slag dump to rise to a considerable elevation so that the cost of this completely unproductive operation is swollen by the necessity of having to lift the slag to considerable heights. The broad question of slag disposal is outside the scope of this report but, given that such a procedure is sometimes unavoidable, it is perhaps worth while enquiring whether there is at least no means of avoiding the elevation of 45 tons of locomotive with every 45 tons of slag, to cite the actual figures applicable to one particular works where a cable-assisted haulage incline is in use. To the inefficiency of such a procedure must be added the risk of dropping fusible plugs or burning firebox plates when working up steep inclines at the end of a heavy haul.

The locomotives go up with the slag ladles to move them on the top to the actual point of tipping and because they are required for the act of tipping, which is generally carried out by chains attached to the lip of the ladle which pass over pulleys to a hook between the buffers. When the ladle is to be tipped the drawhook of the next vehicle is detached from the drawbar and slipped over the chain hook, and the ladle-carriage wheels are scotched. In this way the locomotive can tip a number of ladles in succession, without moving from its position at the end of the train.

In practice this operation is of an extremely harsh nature, especially with slag-ladle cars of light construction. The ladles often stick and the vehicles may easily be pulled over the wooden scotches and derailed. Broken chains and lugs and other damage to ladles and cars are common, and the effect on the locomotive is as severe as the starting of ingot bogies with seized-up bearings. It appears that the reason why such a practice has persisted is because of the low first cost of this simple equipment.

The practice of emptying the slag in the liquid condition into troughs from a stoppered hole in the bottom of the ladle is in use at works where the slag can be delivered straight to a crushing belt for manufacture into tarmac. This leaves only an occasional tipping operation to remove skulls and is a reasonably satisfactory solution of the problem when it is possible.

In other cases self-tipping ladle cars are the most satisfactory solution. The self-tipping ladles now available are operated either pneumatically or by steam ; the pneumatic type could be operated by air compressed electrically at the site in the absence of the locomotive.

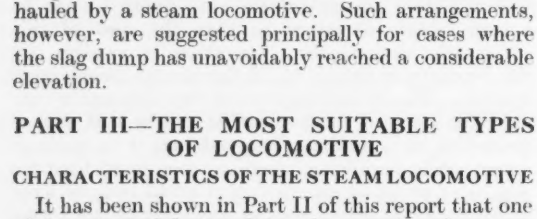
The movement of the ladles on the top of an elevated dump, if the locomotive is left behind at the foot of a main cable haulage, is a rather more difficult problem, because the track is moved from time to time as the dump grows. The elimination of the cost of lifting the locomotive would, however, justify a good deal in the way of extending the haulage system by winches and ropes, especially if electric power is supplied to the site for the main cable haulage and for tipping. Where no cable-haulage assistance is provided for the main ascent, this could be incorporated in a scheme for the provision of power to operate self-tipping ladle cars when the gradient is sufficiently steep to necessitate the division of the train when hauled by a steam locomotive. Such arrangements, however, are suggested principally for cases where the slag dump has unavoidably reached a considerable elevation.

PART III—THE MOST SUITABLE TYPES OF LOCOMOTIVE

CHARACTERISTICS OF THE STEAM LOCOMOTIVE

It has been shown in Part II of this report that one of the principal factors fixing the capacity of a steam locomotive to discharge the duties required in an iron and steel works is the tractive effort it can exert at starting, to overcome the resistance to starting of indifferently lubricated rolling stock ; and for this reason emphasis has been laid on the importance of taking steps to reduce this resistance.

It is a characteristic of the steam locomotive that its power increases with the speed. If the action of the engine and valve gear were perfect and the capacity of the boiler to generate steam unlimited,



	Cylinder Size	Wheel Dia.	Steam Pressure, lb./sq. in.
Loco A ..	.. 18 × 26 in.	4 ft.	170 dropping to 150
Loco B ..	.. 16 × 24 in.	3 ft. 8 in.	170 ,, ,, 150
Loco C ..	.. 14 × 22 in.	3 ft. 4 in.	160 ,, ,, 140

Fig. 5—Horse-power (reckoned at rim of driving wheels) of typical steelworks locomotives in full gear and drawing on storage capacity of boiler

the increase of power would be a simple linear function of the speed. The effect of the action of the engine on the power characteristic has been discussed by the writer elsewhere (*loc. cit.*). As regards the boiler, locomotives of the type used in works rarely run under steady conditions for more than a few minutes at a time. As the steam storage capacity of the boiler is considerable it is possible to consume steam for such limited periods at a greater rate than it is generated, and it is the universal practice in steelworks to work the locomotives with full regulator opening and in full gear for all heavy duties. This means that the locomotives can exert a surprisingly high horse-power for short periods if they can be worked up to a good speed.

Figure 5 shows the power characteristics of three typical steelworks locomotives : locomotive A having two 18 × 26 in. cylinders, 170 lb./sq. in. boiler pressure, and driving wheels of 4 ft. 0 in. dia. ; locomotive B, 16 × 24 in. cylinders, 170 lb./sq. in. pressure, and 3 ft. 8 in. wheels ; and locomotive C, 14 × 22 in. cylinders, 160 lb./sq. in. pressure and 3 ft. 4 in. wheels. It is assumed that the locomotive accelerates for a period at full regulator and in full gear (75% cut-off), during which time the boiler pressure falls by 20 lb./sq. in. It will be understood that such horse-powers can only be attained for short periods and do not correspond to the characteristics appropriate to main-line-railway working where shorter cut-offs would be used for continuous running. This, however, is precisely what is meant by the frequent references to overloading of the steam locomotive in steelworks in earlier sections of this report, and we see why such locomotives can, if given level space to get up speed, surmount short gradients for which, in normal working, locomotives of much greater power would be required.

Now the characteristics of all types of internal-combustion engine locomotives are essentially different in that the engine revolves within a limited range of speed, giving a more or less constant power, the road speed being varied by altering the transmission ratio by mechanical, electrical, or other means. When a train is started the actual power required is low, so that a Diesel engine of quite moderate power will start a train of heavy weight, provided it is geared low enough and the locomotive has sufficient adhesion weight. But such a locomotive will not increase its power as the speed rises to the extent that a steam locomotive does.

This important fact has been repeatedly overlooked in the past, partly because the reserve of power which the steam locomotive possesses in its boiler is not always realized, and partly because no formula has been available in the past whereby the engine horse-power at increasing speed could be readily calculated. The result is that Diesel locomotives of inadequate power have frequently been supplied to replace supposedly equivalent steam locomotives, and whilst they have been able to start the loads prescribed, they have been unable to accelerate them to the speeds required for efficient working or to surmount short steep gradients.

There has been a strong commercial incentive favouring this tendency to underestimate the power required of a Diesel locomotive, because its capital

cost rises steeply with the power, and passes that of a steam locomotive above about 200 h.p. Moreover, owing to the more even torque, it is safe to allow a higher adhesion factor with a Diesel locomotive, so that a machine of lighter weight can be safely trusted to get a specified train on the move. (The tractive effort which can be exerted at starting by a locomotive of any type is, of course, limited by the weight resting on the driving wheels. It is generally the case with all types of locomotive that the engine is capable of slipping the wheels except when the rails are very dry and gritty. As regards ability to start a train, therefore, the matter is purely one of weight, except for the advantage of the more even torque possessed by the Diesel locomotive.)

In steelworks practice the ability to stop a train is no less important, and here the engine torque has no influence whatever. If the weight of the locomotive is insufficient the train will just push it along with all the locomotive wheels locked by the brakes. At one works there are no blast-furnaces and therefore no heavy ore, slag, or hot-metal duties, and the steel is cast in pits, so there is no ingot-car problem. The locomotives in use are, therefore, of the smaller type, not exceeding 32 tons in weight. But difficulties nevertheless occur due to the light weight of the locomotives, because ingots and slabs imported from other works are frequently delivered in 50-ton bogie wagons which are too heavy for these locomotives to hold. When we take into account the heavy weight of the vehicles used on most of the bulk-handling duties in a works with blast-furnaces, and the advantages of using even larger vehicles for the transport of hot metal and slag, it will be seen that, except possibly for certain very restricted duties, the use of locomotives of any type of lighter weight than the existing steam locomotives is out of the question, quite apart from the power they can exert.

Even at the risk of labouring the point, it may be added that another reason why it is fatal to be misled into buying Diesel locomotives of inadequate weight and power for steelworks is the necessity of having a very strong frame to withstand the shocks associated with the handling of heavy weights and badly lubricated cars. The Diesel engine is, in fact, more susceptible to serious damage if such shocks are directly transmitted to the crankcase, and as has already been indicated, the writer is of opinion that in any event steps should be taken to provide well-designed free-running rolling stock before considering the use of Diesel locomotives on duties of this nature.

POWER REQUIRED OF DIESEL OR DIESEL-ELECTRIC LOCOMOTIVES

From the foregoing it will be clear that whereas a steam locomotive may develop the necessary power for short periods to handle the maximum load it can be relied upon to start, Diesel or Diesel-electric locomotives are limited rather by their ability to develop sufficient power to accelerate quickly the loads which they are capable of starting.

For all bulk-handling duties the power required can best be estimated by calculations of the type represented by Fig. 1, though in many cases it will be necessary to take into account the additional power required to accelerate the load to the required speed from a start on an adverse gradient, and sharp curves have also to be taken into account as a cause of increased rolling resistance. It was explained in the introduction (p. 37), however, that it would be uneconomic to provide a special size of locomotive for every duty, and it is possible to propose two or three standard sizes of locomotive on the basis of the discussion in Parts I and II of this report, on the duties to be performed.

The heaviest duty in any well-planned works will generally be the elevation of bulk material to blast-furnace bunker level or open-hearth-furnace stage level. If it is decided that this must be done by locomotive, we shall require in a modern plant of high capacity a minimum of 600 h.p. A locomotive of this power would weigh 60–90 tons and, assuming electric transmission to be specified, it would just be able to deal with a 600-ton train on a gradient of 1 in 70 or a 300-ton train on a gradient of 1 in 30. To allow for extra resistance on curves or for acceleration from rest reasonably quickly, it is desirable to have some margin in hand. It is suggested, therefore, that 700 h.p. is a suitable figure for a standard heavy-duty steelworks locomotive.

The data presented in this report show that on all bulk-handling duties the cost per ton falls as the loads taken by the locomotives increase, and indeed this is only to be expected. It follows that it would be advantageous to use the heaviest 700-h.p. locomotive on all duties such as slag disposal, provided the track layout enables a sufficient number of vehicles to be taken at a time. If, therefore, a locomotive of this capacity were standardized it would probably be required in sufficient numbers to enable an appreciable reduction in price to be made in course of time.

For the miscellaneous marshalling duties, such as the movement of finished products to the main-line sidings, the maximum train load that it would be economical to deal with is the longest rake of wagons delivered to and removed from the exchange sidings by the main-line railway, and for the greater part of their time the locomotives would be dealing with smaller numbers of vehicles. If it is decided that the locomotive should be able, when necessary, to move at one haul a full rake of wagons, the requirements are similar to those for a main-line shunting locomotive, and the experience of the L.M.S. Railway shows that an engine power of 350 h.p. is necessary.

Many existing works manage with steam locomotives of power corresponding to curve C in Fig. 5, dividing full trains handed over by the railway company when necessary. Certain duties within the works, involving principally the setting and marshalling of individual vehicles, are well within the capacity of this limited power. A corresponding Diesel locomotive would be approximately 200 h.p. with a weight of about 26 tons. Such a locomotive is generally to be found within the range of standard types listed by firms making Diesel locomotives with mechanical transmission, and is therefore available at an economic price (£7000–£8000) if special considerations favour the use of a locomotive of such limited power. It is to be emphasized, however, that

such a locomotive is even lighter than the equivalent steam locomotive and has a correspondingly inferior braking force, and it is considered that in normal cases and for all new works the second standard locomotive should be of 350 h.p. This locomotive will have a rather greater starting tractive effort than a steam locomotive corresponding to curve A in Fig. 5 —a desirable feature of which full advantage can be taken—but it will be less powerful than the steam locomotive at speeds in excess of 10 m.p.h. In a large works where the lifting of bulk materials by locomotive is avoided and no long steep gradients have to be negotiated, no need for the heavy 700 h.p. would arise, and the suggested 350 h.p. locomotive would be capable of dealing economically with all the heavy duties, including slag disposal.

A third standard size of locomotive is required for handling the charging bogies on the open-hearth-furnace stages of melting shops of the type favoured for the new steel plants now planned. Trains of bogies carrying scrap and other feed materials have to be moved from the scrap-handling and raw-materials bays to charge-holding roads on the furnace stage, and thence on to the turnouts leading to the furnace line, whence they are drawn into position in front of the furnaces by the chargers. It is recognized in the designs of the new plants that it would be inefficient to lift the scrap to stage level after loading into pans on these cars, because of the low ratio of useful load to gross train weight; it is arranged, therefore, that the whole of this duty is at stage level. The length of the trains is also limited by the congested track layout to be accommodated within the limits of the melting-shop building, so that we have here a special case of a continuous self-contained duty requiring a limited power. Locomotives of 350 h.p. would in any case be too large for furnace-stage work.

It is interesting to note that there is at least one existing example in this country of a plant with a self-contained furnace-stage railway system at stage level on which small Diesel locomotives are used with complete satisfaction. For a modern plant of high output it would be necessary for the locomotives to be able to haul trains of twenty bogies with a gross train-load of 200 tons. Allowing for the extra resistance due to the sharp turnouts inseparable from such a compressed track layout, a locomotive horse-power of 150 should be ample for this duty. Naturally there is no occasion for speed in excess of 10 m.p.h., but quick acceleration from rest is essential, and a locomotive of this power should be able to accelerate a train of 200 tons from rest to a speed of 7 m.p.h. on the level in 30 secs., assuming a rolling resistance of 15 lb. per ton.

AVAILABILITY OF LOCOMOTIVES

It was stated at the end of Part I of this report that the possibility of obtaining an economy from the use of Diesel locomotives would be largely dependent on how much extra tonnage per hour could be handled by Diesel locomotives. The preceding paragraphs, showing that to deal expeditiously with steelworks duties locomotives of relatively high power would be required, emphasize the importance of this question, since the ratio of the capital cost of such locomotives to that of steam locomotives of the type at present employed will be correspondingly greater.

It has already been shown in Part I that features of the railway layout of existing works have a dominating effect on locomotive costs that far outweighs any gain likely to be achieved by changing to another type of locomotive. They exercise this effect by restricting the tonnage of traffic hauled by the locomotive per hour in one way or another, and the statistics given show that the lower the tonnage handled per hour the higher the cost. Now, the potential saving of a Diesel or electric locomotive lies in the lower fuel consumption, and this saving will be greater the more work the locomotive does. In the extreme, if the locomotives did no work at all there would be no saving. On the other hand heavy Diesel locomotives cost more in interest and depreciation, but this excess cost will be proportionately less the more work the locomotive does, provided it is not worked so hard as to wear it out prematurely, since capital charges go on at a steady rate irrespective of whether the locomotive works or not.

The effect of these conflicting factors is shown diagrammatically in Fig. 6. These curves not only show the relationship between the anticipated costs for Diesel and steam on the basis of the figures given in Part I, but also the effect on both of increasing the intensity of working. Thus, assuming that Diesel locomotives are to replace steam locomotives on existing duties, without any modification to the duties themselves, it will be seen that an appreciable saving can only be expected on those duties involving the steady handling of large tonnage. But if a Diesel

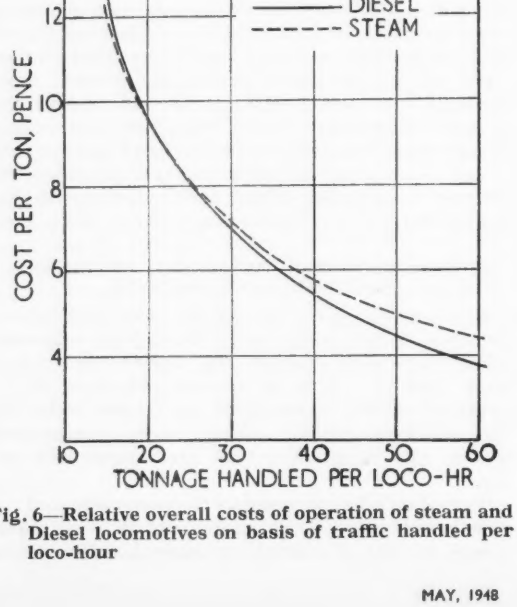


Fig. 6—Relative overall costs of operation of steam and Diesel locomotives on basis of traffic handled per loco-hour

locomotive of equivalent power can deal with a greater tonnage per hour by being available for actual work for a greater proportion of the total shift time, then considerable savings are possible.

It is agreed by traffic managers at most steelworks that on an average 8-hr. shift worked by steam locomotives, 6 hr. are occupied in actual work, half an hour for a mealtime, half an hour for locomotive duties, 40 min. for coaling and watering, and 20 min. in traffic delays. The last item of course is a variable quantity and will depend on the track layout, but these are broadly representative figures for existing works. Of the total lost time of 2 hr., 70 min. can potentially be regained by the use of Diesel or electric locomotives. Assuming that the nature of the duties is such that full advantage could be taken of this increased availability this would be equivalent to an increase of 20% in the tonnage handled per locomotive-hour, without any alteration of the loads taken on each haul.

Taking an existing duty in which the hourly tonnage handled is 30, it will be seen from Fig. 6 that no appreciable saving can reasonably be counted on by the substitution of a Diesel locomotive on that duty if the existing arrangements are such that the locomotive has to work intermittently as the process requires and can refuel during periods of waiting. This is naturally a state of affairs which every traffic manager aims at and which can be approached more or less closely on some steelworks duties where a certain amount of attendant waiting is unavoidable, *e.g.*, for casting and tapping times. If, however, the work is continuous and is discharged purely at the locomotive's rate as distinct from the process rate, then the saving consequent on handling 20% of increased tonnage per hour by the Diesel locomotive would amount to the difference between 7·2*d.* and 5·9*d.* per ton, or 18%.

It is worth while considering the three proposed standard sizes of Diesel locomotives separately from the point of view of the possibility of making full use of their increased availability on the particular duties to which each would be allocated. Taking first the smallest locomotive, this is proposed for a specific duty, namely, the handling of cold charge materials on open-hearth-furnace stages with scrap-handling and raw-materials bays at stage level.

In a separate investigation in progress, the movements of such a locomotive have been closely studied in relation to the large melting shops now planned. The total amount of materials to be handled on charging bogies in these new plants approaches the maximum that can be handled in this manner by the stage railway systems. Two locomotives is the maximum number that can work simultaneously on this duty without getting in each other's way, and in fact the use of additional locomotives would do little more than add to the proportion of idle time spent by each. But the two locomotives must work fairly intensively throughout each shift with very few intervals at rest of more than a few minutes' duration.

In these circumstances the liability of the locomotives to be absent for fuelling or other duties for periods in excess of 10 min. would cripple the operation of the plant unless a standby locomotive was always manned and available at such times. It would seem, therefore, that with the increasing capacity of melting shops this is becoming a duty for which an alternative to the ordinary steam locomotive is essential. The possible use of the accumulator type of steam locomotive will be referred to later, but only Diesel or electric locomotives can approach 100% availability on a duty of this nature, and as electric locomotives present difficulties in connection with the collection of current, it may be said that this duty in new plants of the type now projected is a particularly favourable one for the realization of the full advantages of the Diesel type of locomotive. Moreover, as the power is below 200 h.p. the locomotives would almost certainly be of the mechanical transmission type and the capital cost would be much less in excess of that of corresponding steam locomotives than in the case of the large Diesel-electrics.

Turning now to the standard locomotive of 350 h.p. for general duties, it should be possible to take advantage of the increased availability during each shift on all marshalling and shunting duties that proceed steadily irrespective of the events in the plant, provided the track layout enables such work to proceed uninterruptedly.

This last proviso is really the crucial factor which determines whether a Diesel locomotive will give a financial saving or not, and it is a proviso which cannot be met in many existing works. For example, where a works railway layout is of the type where the tracks are little more than extended sidings, with no through-running roads always clear of standing vehicles, two locomotives are often required to deal with certain duties simply because there would be endless delays in getting one locomotive round to the other end of the train. Each of those locomotives may have a good deal of enforced idle time because it is more or less penned in a certain part of the plant, and a good traffic manager will see that servicing duties are carried out during that time. In such cases the potential saving is negligible, or may even be negative if, through the unavoidable idle time, the tonnage handled per locomotive hour is near the left-hand end of the curves in Fig. 6.

Again, there are certain duties, especially the haulage of hot-metal trains and the transfer of ingots from the casting bay to the stripping shed, where, as has already been mentioned, a certain amount of attendant waiting for tapping times is inevitable, and it would be difficult to handle a greater tonnage per shift unless the duties of more than one steam locomotive could be combined.

It is impossible to consider in detail all the cases that can arise, but the broad principle applies throughout. It is a principle familiar enough to traffic managers because it applies equally to the full utilization of locomotives of any type. But traffic managers are well aware of the difficulty of securing a sufficient degree of flexibility in the allocation of locomotive duties to ensure that each locomotive can always be moved from its primary work during slack periods to other duties. It is sometimes stated that locomotive drivers resist transference from one job to another, but most works have arrangements whereby the necessary instructions can be immediately

conveyed to the drivers, and there is little doubt that the causes of idle time are in most cases inadequate track facilities. Where idle time is unavoidable the conditions are unfavourable for changing to Diesel locomotives; those duties are favourable in which the increased availability of the Diesel locomotive can be made full use of in a correspondingly increased tonnage handled per hour.

Like the small 150 h.p. locomotive, the large 700 h.p. locomotive is for special duties. There are few instances in existing works where a locomotive of such power is required; its adoption in new works arises directly from the necessity of handling far greater quantities of material per hour to cope with the greatly increased capacity of modern furnaces. It may be assumed that where such a locomotive is projected it can be fully utilized throughout at least two shifts per day, otherwise it would be more economical to take smaller loads at a time with locomotives of smaller power. In such cases a very high hourly tonnage will be handled and the conditions are particularly favourable for the use of Diesel-electric locomotives. On the other hand, idle time or work on light loads will be far more wasteful in the case of such a locomotive, and it would be uneconomical for such locomotives to be used regularly for duties other than those for which they are intended.

MAINTENANCE OF DIESEL LOCOMOTIVES

Before passing on to discuss features of alternative types of locomotives other than their power, it may be appropriate at this stage to consider what is involved in the maintenance of locomotives with Diesel engines. It will be recalled that on the basis of the experience of the L.M.S. Railway, it has been assumed throughout the comparisons of operating costs in this report, that the cost of maintenance per service hour will be about the same for Diesel and steam locomotives.

The 350 h.p. locomotives with which the L.M.S. Railway have obtained their experience have electric transmission, the maintenance of which has never presented any particular difficulty because it can be carried out on similar lines to the repair of the motors and control equipment of the company's electric trains. This should also be the case in most steelworks where electric transfer cars and cranes have been successfully maintained for many years.

Where mechanical gearboxes or hydraulic couplings are used maintenance is more specialized and so far as the operating firm is concerned resolves itself largely into a matter of replacement of complete units when necessary. It is of great importance that transmission units of this type should be amply robust for their duty, when they will seldom need attention other than regular lubrication.

The question of maintenance centres, therefore, on the Diesel engine itself, in which wear of the cylinder liners, pistons and piston rings, and bearings, must be periodically corrected, and the injection mechanism and valve gear checked and adjusted. Wear is much more critical in an internal-combustion engine than in a steam engine. It must be kept within much finer limits, and when these are exceeded it is generally remedied, except in the case of bearings, by replacement of the parts concerned rather than by remachining. Where rectification is occasionally carried out, as in the case of crank pins, it involves a precision grinding operation which will generally be beyond the scope of a steelworks engineering shop.

Similarly any accidental stresses which slightly distort the main structure of the crankcase will have more serious consequences than similar shocks to a steam-locomotive frame, and will generally involve an immediate overhaul of the whole engine to restore crankshaft alignment within the fine limits of accuracy which must be maintained.

It will be seen, therefore, that the essence of the matter is the length of time during which one can safely assume that wear in normal working will not exceed certain limits. This is not a fixed period for any given type of engine, but can vary greatly according to the cleanliness of the fuel oil, lubricating oil, and air which circulate in the engine, and the regularity with which routine inspection, cleaning, and adjustment are carried out. These are consequently matters of the greatest importance, and on the attention which is devoted to them will depend the achievement of an overall maintenance cost comparable with that of the steam locomotive.

As regards the actual work of inspection and stripping of large Diesel locomotive engines, this is greatly facilitated by the excellent accessibility of modern designs. In the case of the engines of the L.M.S. Diesel-electric shunting locomotives, for instance, all bearings, main and big end, can be removed through the crankcase doors. There are separate cylinder covers for each cylinder and the piston and connecting rod can be lifted up through the top of the cylinder. The camshaft is in sections, any one of which can be removed independently, and individual cams can be removed and replaced.

Special techniques are required, however, for measuring the amounts of wear which determine the necessity or otherwise for replacement, and for checking adjustments. Crankshaft alignment is one of the most important indications of the condition of an engine and this should be checked at regular intervals. The correct stressing of big-end bolts is another example of a special technique which fitters have to learn. On the larger engines remetalling of bearings will be a normal overhaul procedure, and the L.M.S. Railway have found it possible to eliminate hand bedding-in by fine boring to the actual measurements of the crank-pin diameter. The regular testing of injectors is essential, as well as cleaning when necessary, and for testing, a small hand pump and pressure gauge to give a spray at 2500 lb./sq. in. are necessary. Faulty injectors have to be sent to the makers for attention.

It is not intended here to give a complete guide to the maintenance of Diesel locomotives,* but only to instance typical operations to give some idea of what it involves. Broadly, it may be said that less repairing

* An excellent detailed account can be found in the paper on "The Maintenance of Diesel-Electric Shunting Locomotives of the L.M.S. Railway," by C. E. Fairburn, *Journal of the Institution of Locomotive Engineers*, 1944, vol. 34, p. 212.

of parts is required than in the case of steam locomotives, replacements being obtained from the makers, but that a finer standard of fitting is necessary, mainly in making measurements and adjustments rather than in hand work. The makers of Diesel engines are generally ready to supply fitters to work at the operating firm's shops during overhauls and to train their own staff. Major overhauls which, if routine maintenance is carefully carried out, need not take place at intervals of less than three years, thus present no real difficulties to the engineering departments of iron and steel works.

Routine maintenance is, however, all-important, and whilst it comprises mainly, so far as the engine is concerned, such simple tasks as the cleaning of filters, checking for leaks, testing of lubricating oil, grinding in of valves, and the regular inspection of the working parts and their lubrication, provision must be made to see that a proper maintenance schedule is worked out and that it is strictly adhered to. Most of this work can be done at fortnightly intervals, but the cleaning of oil filters and attention to the brake gear of the locomotive will need to be done weekly.

Nothing has been said so far of availability in the sense of the proportion of days in the year during which the Diesel locomotive can remain in service, but some advantage can be gained in this respect if a maintenance schedule is carefully planned and carried out. Locomotives of this type need only return to the running shed once a fortnight and between these visits they can if necessary work continuously provided they have sufficient fuel tank capacity, which is not difficult to arrange.

PROPOSED STANDARD LOCOMOTIVE TYPES

The general conclusion to be drawn from the foregoing discussion is that for certain duties in new steelworks Diesel locomotives offer an advantage of crucial importance in their ability to work throughout the eight hours of a shift, and for a week or a fortnight of successive shifts, without any interference with continuous operation due to the needs of the locomotive itself; also that there is the possibility of appreciable saving on many other duties, provided advantage can be taken of this increased availability on those duties. Other advantages of the Diesel locomotive, such as the absence of smoke and the better working conditions for the driver, together with the benefits to be obtained by uniformity of maintenance, may well lead to the entire substitution of Diesel for steam locomotives in order to secure the greatest overall improvement in operating efficiency.

It has been suggested that three standard sizes of Diesel locomotive should be envisaged: 150 h.p., 350 h.p., and 700 h.p. Beyond making it clear, however, that their construction must be robust, nothing has been said about other technical features of suitable standard machines. It is not proposed in this report to go into possible specifications in detail. For such a purpose it is suggested that a committee might be formed in conjunction with the locomotive builders. The advantages to be gained by standardization will, however, be obvious from what has been written, especially for the larger sizes. The possible margin of saving in steelworks use is at present small, mainly owing to the relatively high capital cost of the large Diesel locomotive. If individual firms were to evolve, independently, specifications for large locomotives suitable for steelworks use, it is probable that the high development charges would put the capital cost right outside the economic range. On the other hand, the production of agreed standard specifications leading to the building of locomotives in fairly large numbers is the most effective way of bringing the capital cost down. If this can be achieved the possible economic advantages naturally become far more assured.

It is proposed at this stage to consider very briefly only three features of possible standard Diesel locomotives for steelworks, namely, type of transmission, robustness of construction, and wheel arrangement. It is possible to say fairly definitely, for reasons of cost, that the transmission for the 150 h.p. locomotive should be some form of mechanical gearbox with fluid couplings or friction clutches. For the two larger locomotives mechanical transmission could at present only be regarded in an experimental light; present experience indicates that electrical transmission is necessary to give the required smoothness of control with heavy loads and that for locomotives of such size it is not much more costly. If the smaller locomotive of 150 h.p. is required to attain regularly speeds in excess of 5 m.p.h., as will generally be the case in large new plants, some measure of automatic control of gear changing is desirable, as otherwise the trouble of changing from first to second gear may act as a deterrent to the driver and slow down the movement of the furnace feed materials.

Robustness of construction is a matter of the greatest importance which would have to be covered in some detail in a standard specification. It has been emphasized that the onus in this matter lies in the first place on the steelworks user, as many of the conditions in existing works are unnecessarily harsh, and it would be useless to expect satisfactory service from Diesel locomotives in such conditions. Assuming, however, that it is only proposed to introduce locomotives of this type on duties where the track and rolling stock are well planned and in good condition, it is still necessary to design the locomotives so as to be able to withstand, without stressing the engine, impact with exceedingly heavy vehicles or fouling of the track by substantial pieces of metal, and to work without excessive wear of the engine or motors in gritty atmospheres and considerable heat. For the medium and large-size locomotives, three-point suspension of the engine should be an essential feature, and the type and disposition of air filters would need careful specification.

In considering wheel arrangement the question of minimum radius of curvature of the track arises. Nominally the minimum radius shown on the plan of most steelworks track layouts is not less than 90 ft. and in many cases is 150 ft. or more. In practice, the limitations are often more severe than this because curvature is not uniform, and locally, especially in the neighbourhood of rail joints and turnouts, it is sometimes so sharp as to derail a locomotive which could negotiate a carefully laid curve of the correct mean radius.

The standard Diesel-electric locomotives of 350 h.p. that have been developed for main-line-railway shunting duties are of the six-wheeled type with all wheels driven, either directly or through coupling rods. The nose-suspended motors have to be accommodated between the axles, so it is not possible to reduce the wheelbase below about 12 ft., which permits a minimum radius of curvature of 250 ft. This would be too long for almost any existing works, and it is unlikely that the necessary radius of curvature would be maintained indefinitely even in a new works, in view of the alterations in layout that have to be made in every works in course of time. At best it must be said that it would impose a somewhat severe limitation on such alterations to any works starting out with a fleet of fixed-wheelbase six-wheeled Diesel-electrics. In the case of the 700 h.p. locomotive an even greater wheelbase would be necessary.

The conclusion to be drawn from the above is that the double-bogie type of locomotive would be most suitable as a standard for steelworks. There are, of course, other limitations in many existing works such as maximum overall length and headroom, which would make it difficult to accommodate an engine and its transmission of 350 h.p. within the permissible overall dimensions. It has already been indicated that the case for changing to Diesel locomotives is a doubtful one in old works subject to limitations of this kind, and it is considered, therefore, that special limitations of this nature should be left out of account in drawing up an agreed specification for Diesel locomotives. For the small 150 h.p. locomotive no difficulty arises as this can be a four-wheeled machine.

LOCOMOTIVES FOR SPECIAL DUTIES

Practically every steelworks can show examples of locomotives of special type at work exclusively on particular duties. The great majority of these are electric locomotives or cars, taking current from a wire or rail conductor. Coke-oven quenching and charging cars and ingot chariots are more or less standard applications of all-electric traction. Electric transfer cars and scale cars above and below blast-furnace bunkers and under limestone bunkers in steel plants are other familiar examples.

The advantages of electric locomotives are obvious. Fuel is used at a relatively high thermal efficiency whilst the capital and maintenance costs of the power equipment of the vehicles are a minimum. Electricity is available throughout the works and with the increasing use of waste heat a greater proportion of the power is generated at very low cost. The one great difficulty is current distribution, and it is noteworthy that even where electric transfer cars have been in operation for some time there is a tendency to regard the current distribution system as a nuisance and a source of danger. This raises the question whether sufficient attention has been paid to electrical distribution systems for traction in works. Almost every possible disposition of the conductor relative to the track is to be seen in various works, but the arrangements are generally elementary in character. It is not uncommon to find cases where two systems clash, as for instance where the collector pole of a ground-level furnace charger has to be removed to allow an overhead crane to pass.

The objection to ground conductor rails or conduits is the danger and the possibility of frequent short circuits due to falling pieces of metal. It is open to question, however, whether the possibilities of overcoming these difficulties have been exhaustively explored. At present the economic advantages and convenience of electric traction are forcing its universal adoption for special duties of a short repetitive nature, but it is frequently regarded as impracticable for any more complicated movement than a straight run backwards and forwards along a single length of track. Thus one may see, as in one casting bay visited during this investigation, an electric track along one side of the bay on which an electric transporter moves the steel ladles into position for tapping and subsequent casting into pits, and another electric track parallel to the first on which an ingot chariot runs. The track on which ingots are moved, after stripping at the pits, from one side of the bay to the other is, however, not electrified, a steam accumulator type of locomotive being used for this duty. Since special types of self-moving cars are used on the two electrified tracks a separate locomotive would in any case be required for the duty of transferring the ingots to the ingot chariot, but the only reason preventing this from being an electric locomotive is the complication of two track junctions and the fact that more of the conduit conductor, with its element of danger, would be required.

Examples are to be found in various works, of the use of electric traction in one form or another for moving partially finished products from one mill to another. In one case a telpher system is in use for a fairly long journey with several changes of direction. In another example a battery locomotive is used over one special length of track running between two mills. Another application of electric traction planned for early completion at one plant is the transport of ore from a waterside wharf to the ore-stocking ground. This is of particular interest as it includes a number of track turnouts, and current distribution will be by an overhead conductor of similar type to that used on electric railways. For safety, however, it is deemed necessary to limit the D.C. voltage to a low figure and this tends to restrict the design of the locomotive.

All these applications of electric power represent a reduction of the cost of operating the particular duties to which they apply, and it is sound policy to deal with as many regular repetitive duties of this kind as possible in this manner. In most cases, however, the motors are mounted on the same frame as the vehicle holding the material to be transported, so that it is either necessary to carry out all maintenance work *in situ* during weekends or to hold a complete vehicle as a spare. In this respect such electrified railways are in a similar position to electric cranes and conveyors. If electrification were carried out on a wider scale, using locomotives, the advantages of greater flexibility might be added in some of these existing applications, such as traffic between mills, but it would not affect duties requiring special vehicles, often on a wide gauge.

The broad problem of electric locomotives for steelworks railways can scarcely be said to be affected by these special duties, though they contribute greatly to the lowering of the overall costs of works transport. It may, however, be observed that if electric current can be distributed safely to special cars of this kind working in the most congested parts of the plant, it seems worth while considering whether the difficulties of general distribution to works railways are really insuperable. There are very successful examples of electrified railways in quarries and brickworks using both third-rail and overhead-wire systems which have been free from accident for long periods. In these systems the presence of personnel about the track, and the necessity of allowing freedom of movement to excavators, are difficulties which have been met and overcome, but the railways are not so complicated or congested as many parts of a steelworks system. The subject is one which has not been carried beyond this point in the present investigation but might be considered of sufficient importance to justify a separate investigation.

Steam-accumulator locomotives have already been mentioned and possess some advantages over the ordinary steam locomotive for special duties, more particularly in reduced maintenance costs. Indeed, a steam-accumulator locomotive is probably the cheapest of all forms of locomotive to maintain, though strictly speaking it should be debited with a proportion of the costs of maintenance of the stationary boilers generating the steam which it uses. This is usually covered for accounting purposes in the cost of the steam supplied, but in a system employing a number of such locomotives it would probably be necessary to have a special boiler plant, the maintenance costs of which should be added to those of the locomotives themselves. The maintenance cost of the locomotive alone in the case of a steam-accumulator locomotive that has been in service for some years at a steelworks in this country is 1*s*. 2*d*. per service hour.

No great saving in fuel can be expected from steam-accumulator locomotives unless their use enables steam to be generated from waste heat which would otherwise be lost. The steam is used no more efficiently than in the equivalent fired locomotive, whilst the slight increase in efficiency with which it may be generated is offset by the loss due to condensation between the time it is generated and used in the locomotive cylinders.

Considerably improved results in this respect as well as in power and capacity, can be obtained by the use of much higher charging and storage pressures than have hitherto been adopted in this country. The Vienna Locomotive Works, under licence from Ruth's International Accumulators, Ltd., have built a number of locomotives of this type with an accumulator pressure of 1200 to 1700 lb./sq. in. and a capacity sufficient to give 4 hr. operation at an average rate of working before the tractive effort falls below the rated amount. The standard type of locomotive has a weight of 58 tons and a tractive effort of 15 tons, but locomotives having a weight of 82 tons and a tractive effort of 21 tons have been converted to work on this system.

It is, of course, impossible to make use of such high pressures efficiently in ordinary single-expansion cylinders, and the steam is throttled down to 215 lb./sq. in. before admission to the steam chest, but by storing at such a high pressure up to 100–150° F. of superheat can be obtained by carrying the steam, after passing the reducing valve, through the accumulator. It is also found that the heat storage in the steel mass of the drum adds some 30% to the hot-water storage capacity when high pressures of this order are used.

High-pressure-steam accumulator locomotives require, however, special boilers to generate the steam except in cases where it is already proposed to generate steam at very high pressures for power. This would hardly be economic unless a number of locomotives of this type are employed.

The steam-accumulator locomotive must be regarded as suitable only for special duties because it is limited in range. It is possible to conceive charging points in many places throughout a works, but unless they are near centres of intensive traffic their maintenance would be uneconomic. Moreover, the availability of steam-accumulator locomotives during a shift is no better than in the case of fired locomotives. The total time for charging may be no more than for fuelling the ordinary locomotive, but it generally has to be carried out at shorter intervals. Given, however, a duty confined within a short radius of the charging point, with frequent short intervals, during which the locomotive can 'top up' its charge, this disadvantage need not be serious, and as such duties will usually be in the neighbourhood of shops the benefit from the absence of smoke is of importance.

Duties which appear to be suitable are furnace-stage work and the transfer of ingots from casting bay to stripping shed. It is likely, however, that in future plants with furnaces of high capacity the loss of availability due to the need for frequent charging may be a fatal drawback. This point has already been specifically dealt with, and it would have to be examined quantitatively in the greatest detail before a decision to adopt locomotives of this type was made. Where such locomotives could use steam generated on the plant in waste-heat boilers the fuel saving will be a very strong point in their favour.

In investigating the possibilities of using locomotives of alternative types, hourly costs of operation are sometimes quoted which relate to isolated locomotives working on a single duty, such as the steam-accumulator locomotives referred to. It should be emphasized that when certain special duties are selected for operation by locomotives of special type, they not only enjoy the advantage of working in circumstances particularly suitable to them, but also of working continuously on a single routine duty, free from the contingencies, abnormal loads, and delays which are inseparable from the work of a general locomotive. Such figures are therefore usually much more favourable than can be expected in general work. This, of course, is the reason why it is sound policy to employ special locomotives for special duties when they can be fully employed on them. It is, indeed, an intermediate stage between general locomotive haulage and the use of conveyor installations.

Comparisons between the costs of one type of locomotive working on a duty of this kind and another type on general work are, however, quite misleading.

Before leaving the subject of special duties, some mention should be made of the use of electric power in the form of winches with ropes for the movement of single vehicles. There are many cases in existing works where the installation of winches and ropes could save a great many locomotive-hours which, as has been shown, are a costly form of transport. The use of turntables would extend the scope of electric winches, and there is room for the development of a simple but rugged turntable that would work satisfactorily in such places as a steelworks casting bay. Apart from the movements of trucks for loading and unloading, the withdrawal of slag ladles from under steel furnaces is an example of the kind of duty that could be facilitated by this means in existing and congested plants. The general principle would be to withdraw the cars along a short straight length to a turntable where they could be turned through a right-angle for assembly into a train by a locomotive. This would eliminate many awkward curves, often on steep gradients, where locomotives spend a good deal of time waiting about for individual ladles to be filled, and then struggling to draw them out over the inclined curves at low-lying points where moisture tends to accumulate on the rails.

CONCLUSIONS

1. The cost of locomotive haulage per ton of traffic handled varies between 5·7*d*. and 9·9*d*. in a number of representative steelworks, due to differences in the track layout and the type of rolling stock used. (*See* p. 40.*)

2. The cost per locomotive-hour varies inversely with the cost per ton because track limitations restrict the amount of useful work the locomotives can do and consequently their fuel consumption and wear and tear. A low hourly cost is therefore no indication of efficiency. (*See* p. 40.*)

3. There is far more scope for the reduction of the cost of locomotive haulage by proper consideration of track layout and rolling-stock design than by changing to other types of locomotive. (*See* p. 40.*)

4. The heaviest locomotive duties in iron and steel works are the handling of feed materials, ingots, and slag in bulk, and although these give a favourable ratio of tonnage per locomotive-hour, they determine the size of the locomotives required and therefore their capital cost and also cause the greatest amount of wear and tear. (*See* p. 42.*)

5. The lifting of bulk materials through considerable differences of level, as on blast-furnace gantries and steel-furnace stages, requires greatly increased locomotive power as compared with their movement at ground level. The power of the steam locomotive increases with its speed and the boiler has a considerable energy-storage capacity. It is therefore possible to lift useful quantities of material up short steep grades by small steam locomotives by working them to the limit and attaining as high a speed as possible at the foot of the grade ; this is general practice at present. (*See* pp. 45–46, and 50.*)

6. Diesel locomotives give approximately constant power at all speeds and will not give satisfactory service if they are continuously worked to their maximum output. On modern plants with high rates of production Diesel locomotives of relatively high power and cost would be required for the duties mentioned in conclusion 5. (*See* pp. 46, and 50–52.*)

7. The extended use of conveyors for the bulk-handling of feed materials offers a means of avoiding some of these difficulties. A study of the capital and operating costs of large conveyor installations handling similar materials shows that the total cost of moving material by large conveyors is of the order of one-third of the cost of moving it by locomotive, provided the quantity is such that the work of at least one locomotive is replaced. (*See* pp. 43–45.*)

8. It is not at present practicable to handle scrap metal by conveyor, but the extra cost of lifting scrap to stage level on large plants by locomotive as compared with its movement at ground level is so great that it is worth making the elimination of this lift by locomotives a principal aim in developing new methods of material handling and charging for open-hearth plants. (*See* p. 46.*)

9. The reduction of the effective hauling power of the locomotives by the high starting resistance of cars subject to heat and spillage is a serious factor in increasing the cost of locomotive haulage, not only by reducing the tons hauled per locomotive-hour, but also by aggravating wear and tear. The cost of converting ingot cars from plain to roller bearings will, for instance, yield a handsome return on any steel plant with a weekly output of much over 5000 tons, provided a satisfactory design giving adequate protection of the bearing is adopted. (*See* pp. 46–48.*)

10. Stripping of sticking ingots by bumping them on the ingot cars is an indefensible practice, and an alternative means of doing this is illustrated in the report. The whole principle of casting on small railway cars is perhaps questionable from the engineering point of view, and involves a rather extravagant use of costly locomotive power. It is considered that some modern form of pit casting or other methods of moving cast ingots whilst in the moulds are worth considering for future development. (*See* p. 48.*)

11. The cost of slag disposal is avoidably increased in many works by the effect of spillage (referred to in conclusion 9), by a high ratio of tare weight of the ladles and carriages to their capacity, and by using the locomotive for tipping by pulling through chains. This very prevalent method of tipping not only increases the rate of wear and tear of locomotives and rolling stock, but frequently entails the lifting of a ton of locomotive weight for every ton of slag tipped when the slag dump is at a considerable elevation. Modern methods of tipping avoid the use of the locomotive for this purpose. (*See* pp. 48–50.*)

12. Estimated comparative hourly costs of steam and Diesel locomotives of equivalent power in steelworks service, based on costs for large numbers of locomotives in representative steelworks and in main-line railway shunting service, show no decisive overall

* The page numbers refer to the pages of this report on which each conclusion is based.

saving in favour of Diesel locomotives. If, however, the duties are so arranged that the Diesel locomotive handles an additional tonnage equivalent to the time saved by the elimination of refuelling in each shift, an appreciable saving can be effected. (*See* pp. 41–42 and 52–53.)

13. In existing works it would be difficult to fulfil this condition in all cases. Track restrictions frequently hinder the rapid transference of the locomotives from one point to another so that in addition to traffic delays a certain amount of waiting for process events, such as tapping and casting, is unavoidable, and refuelling and servicing can frequently be done during these periods. (*See* pp. 53–54.)

14. The absence of smoke and the better conditions for the driver are advantages which may be considered to justify a change to Diesel locomotives even if no direct financial saving results. Careful consideration should, however, be paid to the duties on which it is proposed to introduce them so that advantage can be taken of the greater availability. (*See* pp. 53–54.)

15. It is essential that locomotives of adequate power and weight should be used. Unless there are other restrictive conditions which prevent full trains as delivered by the main-line railway being handled, a locomotive of about 350 h.p. is required for general steelworks service. If for the reason stated it is decided to use a smaller locomotive, it may suffer from a lack of braking power if required to deal with the heavier types of vehicle which have to be handled in steelworks. (*See* pp. 51–52.)

16. In open-hearth melting shops of the type planned for several of the projected steelworks extensions, where scrap and feed materials are loaded on to charging bogies at stage level, the movement of the charging bogies between the scrap-handling and raw-materials bays and the furnace stage can be treated as a special duty for which locomotives of 150 h.p. would suffice. In plants of very high capacity such a system of feeding the materials can only be worked by a very limited number of locomotives continuously available during each shift. This duty therefore offers a very favourable opportunity for the introduction of Diesel locomotives, especially as standardized machines of this power are already available. (*See* p. 52.)

17. Except possibly for the small 150 h.p. locomotive referred to in conclusion 16, new designs would have to be developed by British manufacturers for steelworks Diesel locomotives of 350 h.p. for general service, and of 700 h.p. for ramp work for feeding open-hearth plants, with scrap-handling plants at stage level and for other very heavy duties. To develop and manufacture such locomotives at the lowest possible cost standard specifications should be agreed upon by the industry. It is suggested they should be of the double bogie type with electrical transmission and that the formulation of a detailed specification might be considered by a committee of the steel industry in collaboration with the locomotive manufacturers. (*See* pp. 55–56.)

18. To ensure that Diesel locomotives operate at a cost no greater than is estimated in this report, steps must be taken to minimize maintenance charges. The overhauling of Diesel locomotives is, in general, by the replacement of worn parts rather than their repair, but the permissible limits of wear are much finer than on steam locomotives. If these are exceeded serious damage to the engine and heavy repair costs may ensue. It is, therefore, necessary to observe a strict routine of inspection and cleaning of oil and air filters, and to train members of the engineering staff to make the accurate measurements and tests required. Apart from this, work outside the capacity of an ordinary steelworks engineering shop, such as the grinding of crankpins, need only occur occasionally, and can be provided for by carrying a few additional major spare parts. (*See* pp. 54–55.)

19. Special duties of a short repetitive nature are frequently carried out by electric traction, with current distribution from the main power stations. Where this can be done the cost of handling the material is minimized, provided the system is adequately loaded. The success of such installations in congested parts of the plant suggests that the difficulties of distributing current safely to electric locomotives operating more flexibly over a wider range may not be insuperable and might be worth separate investigation. (*See* pp. 56–57.)

20. A possible useful extension in existing works of the principle of dealing with special duties by electric power would be the use of capstan winches, in some cases in conjunction with turntables, for setting and moving individual vehicles; for example, the withdrawal of slag-ladle cars from under steel furnaces where there is insufficient room for a favourable track layout. (*See* p. 58.)

21. The steam-accumulator type of locomotive might effect savings on some special duties in existing works, particularly for handling ingots between the casting bay and stripping bay, on account of its low maintenance cost. If numbers of such locomotives were employed special boiler plant would have to be built, and the capital and maintenance costs of this would have to be added to the maintenance cost of the locomotives themselves. In such a case very high storage pressures are recommended. The possibility of using steam generated from waste heat at the point of operation would make the steam-accumulator locomotive extremely economical, for example, for furnace-stage work. But the availability of this type of locomotive during each shift is even more restricted than that of the ordinary steam locomotive, and this disadvantage is a serious one for all duties connected with the flow of materials in plants of very high capacity. (*See* p. 57.)

Acknowledgments

Acknowledgment has been made of the valuable information supplied from sources outside the steel industry. The author would, however, like to add that the report is mainly based on data supplied by the managements and officers of a number of iron and steel companies, and he would like to express his particular indebtedness to the traffic managers, engineers and accountants of these firms, who took very great trouble to extract data in sufficient detail to enable the generalized Tables in the report to be prepared with some confidence that they are representative.

Service Trials of Painting Schemes Applied to a Steelworks Gantry

By J. C. Hudson, D.Sc.

SYNOPSIS

The results of practical painting trials on a steelworks gantry are described and are compared with those of parallel small-scale outdoor exposure tests. Both agree in showing that the efficiency of protective painting schemes applied to steel is greatly increased by removing the mill scale by pickling before applying the paint. In the small-scale tests the average life of two-coat painting schemes over pickled steel exceeded 7·0 years, as compared with 1·5 years for steel prepared by weathering and hand-cleaning. The procedure of coating the steel with linseed oil whilst still hot after rolling was also tried. The results proved better than those for weathered steel but inferior to those for pickled steel, because the mill scale left beneath the paint ultimately gave rise to cracking or local failure of the paint film.

Differences between the performance of the various painting schemes tested were generally of secondary importance in comparison with those associated with differences in the surface preparation of the steel before painting.

Introduction

THIS is the final report on the results of some service trials of painting schemes for structural steelwork commenced in 1935 by the Protective Coatings Sub-Committee of the British Iron and Steel Research Association, with the collaboration of the Appleby-Frodingham Steel Co. Through the courtesy of this Company arrangements were made to paint a large gantry, then being erected at their Frodingham works, on an experimental basis, varying both the surface preparation of the steelwork and the paints applied to it.

Three methods of surface preparation were studied, namely:

(1) The ordinary procedure of exposure to the weather, followed by hand-cleaning.

(2) The application of boiled linseed oil to the steel at the rolling mill whilst the steel is still hot.

(3) Pickling in dilute sulphuric acid.

Four paints in various two-coat combinations were used on different parts of the structure, namely red lead, micaceous iron ore, metallic lead, and French grey. The compositions of the first three paints* are given in Table I.

In parallel with the service trials, a subsidiary series of small-scale tests was conducted in which the same painting schemes were applied to small specimens of ingot iron prepared for painting by similar surface treatments. These specimens were exposed outdoors to the Birmingham atmosphere and the tests on them were concluded in March, 1947, after ten years' exposure.

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* The exact composition of the French grey paint, which weighed 19 lb./gal., is unknown.

SERVICE TRIALS ON THE CRANE GANTRY

(1) EXPERIMENTAL DETAILS

An account of the earlier stages of the experimental work has already been given,† and it will suffice to recapitulate only the main features. Although an attempt was made to follow the detailed history and behaviour of all the members of the structure, it proved practicable to vary the surface treatment fully

† Fifth Report of the Corrosion Committee, *The Iron and Steel Institute*, 1938, *Special Report No. 21*, pp. 362–368.

Table I

COMPOSITION OF THE PAINTS TESTED

	Red Lead	Micaceous Iron Ore	Metallic Lead
Pigment, %	80*	66†	92·1‡
Linseed oil, boiled, % ...	4	34†	3·9
Linseed oil, raw, % ...	...		...
Linseed oil, refined, % ...	14	...	3·9
Turpentine	1	...	...
Liquid driers	1	...	0·1
Weight per gallon, lb. ...	31	21	51§

* Non-setting.
† Approximate value.
‡ Pure lead containing not more than 1·5% of oxide.
§ This paint was formulated on the assumption that the best procedure, from the point of view of preventing corrosion, was to make the pigment concentration as high as possible, but it is now doubtful whether this view is correct. For practical application in the service trials it was found desirable to thin the paint considerably with oil, using rather more than 1 pint of linseed oil per 2-gal. drum, although in the small-scale trials it proved possible to apply the paint as it stood.

only in the case of the principal members of the stanchions, twenty-two in number, carrying the crane runway. Observations on the performance of the painting schemes were therefore limited to these members, which are 20 × 6½-in. joists and 15-in. × 4-in. × 42-lb. channels.

(a) Painting Schemes

The following two-coat painting schemes were used :

(1) One coat of red-lead paint ; one coat of micaceous-iron-ore paint.

(2) One coat of red-lead paint ; one coat of French grey paint.

(3) Two coats of metallic lead paint.

(4) Two coats of French grey paint.

Each of the twelve combinations of these four painting schemes with the three methods of surface preparation was used for two stanchions, one on either side of the gantry, except that scheme (2) was not applied to stanchions that had been oiled whilst hot and scheme (4) was applied to only one such stanchion but was applied to three stanchions that had been exposed to the weather and hand-cleaned.

(b) Surface Preparation

A summary of the observations made on the surface preparation of the stanchions is as follows :

(i) *Weathering and Hand-Cleaning*—After fabrication the stanchions were exposed outdoors for an average period of 19 days (limits 1–51 days). They were then brought back into the shop and painted under cover, after having been cleaned by scraping and wire-brushing.

(ii) *Oiling Whilst Hot*—Boiled linseed oil was brushed on within 20–30 min. after the completion of rolling ; the temperature of the steel was approximately 120° C. (limits 80–170° C.). The time elapsing between this treatment and the application of the first coat of paint varied but did not exceed three days. In the case of the joists cracks were observed in the dry oil film on the web 24 hr. after the oil had been applied.

Table II

AVERAGE TIME SPENT IN CLEANING AND PAINTING

Operation	Man-Minutes per Square Foot for:		
	Weathered and Hand-Cleaned Stanchions	Stanchions Oiled Whilst Hot	Pickled Stanchions
First cleaning at shop	0·86	0·76	0·68
First coat of paint at shop	0·62	0·49	0·41
Second cleaning at site	0·52	0·45	0·53
Second coat of paint after erection ...	1·20	0·84	1·02
Total	3·20	2·54	2·64

Table III

APPROXIMATE THICKNESS OF THE DRY PAINT FILMS. SERVICE TESTS

Painting Scheme	Average Film Thickness (Approximate), mils		
	First Coat	Second Coat	Total
Red-lead/micaceous-iron-ore	3·5	5·5	9·0
Red-lead/French-grey ...	3·7	4·7	8·4
Metallic lead (2 coats) ...	2·6	3·4	6·0
French grey (2 coats) ...	4·6	4·7*	9·3

* Not observed directly but assumed equal to the value for French grey over red lead.

(iii) *Pickling*—The mill scale was removed by immersion for an average period of 1 hr. in 7 wt.-% of sulphuric acid.* On removal from the bath, the steelwork was rinsed by dipping in hot water and finally in lime water. After drying, the sections were stacked under a tarpaulin until the first coat of paint was applied. The interval between pickling and painting did not exceed 19 days, and the stanchions were thoroughly wire-brushed beforehand.

(iv) *Cleaning and Painting*—Average figures for the labour involved in cleaning and painting, expressed in man-minutes per square foot, are shown in Table II. It should be borne in mind, particularly with regard to cleaning, that in view of the special nature of the work considerably more time was devoted to the operations than would hold good for the normal run of production.

There is some evidence that the labour involved is reduced by pickling, as compared with the usual process of weathering and hand-cleaning. This would certainly have been the case if no interval had occurred between pickling and the application of the priming paint coat, which is the ideal procedure, as the necessity for the first cleaning would then have been obviated.

(c) Thickness of Paint Applied

Observations were kept of the weights of the paint applied to the individual stanchions. The results are best expressed in terms of the equivalent thicknesses of the dry paint films calculated from the weights of paint used. These are recorded in Table III. It should be emphasized that the figures are approximate, particularly in the case of the French grey paint, where it has been necessary to assume that the paint contained no volatile matter.†

* The acid concentration fell to about 3% at the end of a run.

† At the time that these tests were initiated (1936) it was regarded as sufficient to record weights of paint. The importance to be attached to the paint film thickness has become apparent in recent years as a result of the researches of the Protective Coatings Sub-Committee, so that if this experiment were repeated now the volatile content and any other data necessary to deduce the film thickness would be determined for all the paints.

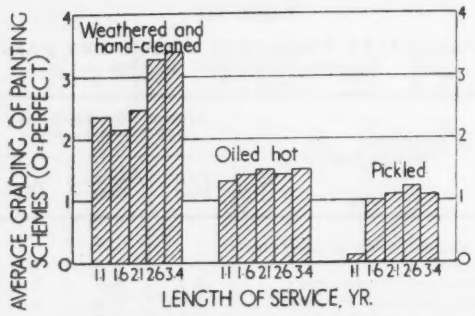


Fig. 1—Effect of surface preparation on the protection afforded by painting schemes

(2) EXPERIMENTAL RESULTS

The painted stanchions were inspected at intervals of approximately six months from September 1937 until 1939, when the outbreak of war rendered it necessary to discontinue observations.

The procedure adopted at these inspections was to grade the condition of the painting scheme on each stanchion on the following basis :

0 Perfect.
1 Very good.
2 Signs of failure.
3 Marked signs of failure.
4 Very marked signs of failure.

Separate assessments were made for each of the outer surfaces of the two outer main joists, and a single joint assessment for their inner surfaces, so that three marks of from 0 to 4 were assigned to each stanchion.* Comparisons between individual stanchions are complicated by the fact that some are sheltered by adjacent buildings, whilst the paintwork on others suffered mechanical damage from materials carried by the cranes and other causes. Allowance has been made for the latter factor, and it is considered that the overall averages of the gradings for the various methods of surface preparation or the different painting schemes give reasonably accurate comparisons of their relative merits.

The results showed that any differences between the various painting schemes were masked by the effects of the differences in surface preparation. It will suffice, therefore, to confine attention to the latter factor. The results of the experiment in this respect are adequately portrayed by the diagrams reproduced in Fig. 1. These relate to the average gradings of all the stanchions prepared for painting, respectively, by :

(i) Weathering and hand-cleaning.
(ii) Oiling at the mill whilst hot.
(iii) Pickling.

Figures are given for five successive inspections made after periods of from 1·1 to 3·4 years approximately, counted from the application of the second coat of paint.†

It will be seen that the painting schemes applied to the steel that had been prepared by weathering and hand-cleaning showed signs of failure at the earliest inspection after 1·1 years. Deterioration increased progressively on these surfaces until at the last inspection after 3·4 years the stage had been reached at which they needed repainting. The detailed reports made at that inspection show that flaking-off of paint was recorded on 24 of the 27 surfaces of this type. The average figure for flaking was 2·1% of the surface area, and the maximum figure observed in any one case was 10%.

In contrast to this the gradings of the stanchions receiving special treatments, *i.e.*, oiling at the mill whilst hot, or pickling, remained low throughout and the average grading figures did not approach 2 (signs of failure) even by the end of the test after 3·4 years.‡ At this time flaking of the paint was recorded on only one surface of these two types. This was to the extent of 0·5% and occurred on a joist that had been oiled hot at the mill.

Of the two special treatments, pickling is to be preferred to hot-oiling because, as already mentioned, cracks were observed to form in the paint film in the latter case. These cracks were probably due to cracking of the mill scale itself. The cracks developed further on exposure and, as noted above, had led to 0·5% of flaking in one case by the time the observations were discontinued.

These differences in the behaviour of the painting schemes due to differences in surface preparation are illustrated by a series of photographs shown in Fig. 3.

The gantry was repainted in July 1944, using the same painting scheme throughout, namely, one coat of red lead and one coat of French grey, and it was considered of interest to make a final inspection in August 1947 in order to ascertain whether the effects of surface preparation or paint performance had persisted after repainting. Each stanchion was graded in the same manner as before, with the following results :

Surface Preparation before Painting	Average Grading
Weathering and hand-cleaning ...	2·33
Oiling at the mill whilst hot ...	2·00
Pickling	1·75

Thus, there is evidence that the effects of the initial surface preparation had some influence on the behaviour of the second painting although, as will be obvious from Fig. 2, in which the distribution of the gradings on individual stanchions is compared with that observed at the last inspection of the old paints in December 1939, the differences arising from these had been greatly reduced.§ The fact that these differences are observed in the case of the second painting is clearly associated with the condition of the old paints at the time of repainting, which in turn

* With the exception of the first two inspections, at which only the two outer surfaces were graded.

† The times given are average values for all the stanchions. Approximately six months elapsed between the completion of the first one and the last.

‡ The low grading for the pickled surfaces at the first inspection is probably an underestimate.

§ It will also be seen from this diagram that from a statistical point of view the correlation between the two sets of observations, although of the expected type, is not numerically high. This was confirmed by attempts, necessarily very approximate, to correlate the behaviours of individual stanchions at the two inspections.

was largely determined by the initial surface preparation. It is obvious that the bad effects of an inferior method of surface preparation can be made good by more frequent cleaning-down and repainting, but it is probable that in most cases such a procedure will be less economical than devoting additional attention to correct surface preparation; it will certainly be more expensive in labour and materials.

SMALL-SCALE FIELD TESTS

(1) EXPERIMENTAL DETAILS

(a) Type and Size of Specimen

For the small-scale field tests specimens of ingot iron, each measuring 6 × 4 × ⅛ in., were used. These were supplied in the as-rolled condition, but the surface treatment before painting was varied as described below.

(b) Surface Treatments Before Painting

The surface treatments given to the specimens before painting resembled as closely as was possible on a laboratory scale the practical procedures applied to the steelwork of the gantry itself. A fourth treatment was added, namely, pickling in sulphuric acid followed by treatment with phosphoric acid. Details of the methods used are as follows.

(i) *Weathering and Hand-Cleaning*—The specimens were exposed out of doors at Birmingham for three months, from January to March, 1937, after which the average descaling for both surfaces was 35%. Before painting, the specimens were scraped and wire-brushed.

(ii) *Treatment with Linseed Oil Whilst Hot*—The specimens were heated on a sand bath to 150°; they were then removed, brushed free from sand, and immersed for about 1 min. in raw linseed oil. After removal from the oil they were allowed to drain, brushed down lightly, and suspended vertically to dry.

(iii) *Pickling in Sulphuric Acid*—The specimens were immersed for 1 hr. in sulphuric acid, approximately 20% by volume, at 40° C. On removal from the bath they were rinsed in water, immersed in lime water at about 80° C. for 1–2 min., rinsed quickly in water to remove the adhering lime, dried rapidly, and painted whilst still hot.

(iv) *Pickling in Sulphuric Acid Followed by Phosphoric Acid*—The mill scale was first removed by immersion for 1 hr. in the sulphuric acid bath as above. The specimens were then rinsed in hot water and immersed for 3–5 min. in a phosphoric acid solution containing 3·5% of phosphoric acid and 0·4% of iron, at 85° C. They were dried quickly and painted whilst still hot.

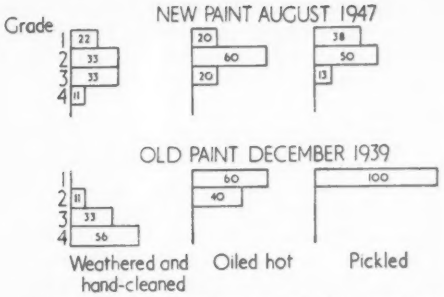


Fig. 2—Percentage distribution of the gradings of individual stanchions. The figures relate to each group of stanchions receiving the same surface preparation; for example, in December, 1939, 60% of the stanchions that had been oiled hot were in grade 1

(c) Painting Schemes Applied

Each of the four painting schemes tested on the gantry (*see* page 61) was applied to two specimens in each of the four surface conditions detailed above, *i.e.*, each painting scheme was applied to a total of eight specimens. In addition, two pairs of specimens prepared for painting, respectively, by weathering and hand-cleaning and by pickling in sulphuric acid were painted with two coats of the Corrosion Committee's standard red oxide paint. This paint contains 60% of iron oxide (natural Spanish) and the medium consists of a mixture of refined and boiled linseed oils with small additions of thinners and driers. The total number of specimens involved in this investigation was thus thirty-six.

(d) Painting

The painting commenced on 3rd March, 1937, and was completed by 10th March. An interval of 5 days elapsed between the first and second coats of each painting scheme. As already noted, the pickling operations were timed so that the priming coats were applied to the specimens concerned whilst they were still hot. Values for the average dry-paint film thickness for each painting scheme tested have been calculated from the observed weights of paint applied

Table IV

APPROXIMATE THICKNESS OF THE DRY PAINT FILMS. SMALL-SCALE FIELD TESTS

Painting Scheme	Average Film Thickness (Approximate), mils			
	First Coat	Second Coat	Total Calculated	Total Observed August 1947
Red-lead/micaceous-iron-ore	2·9	2·8	5·8	4·0
Red-lead/French-grey	2·4	2·8	5·2	3·1
Metallic lead (2 coats)	1·9	1·7	3·6	2·7
French grey (2 coats	1·4	1·1	2·6	...
Red oxide* (2 coats)	1·4	1·6	3·1	...

* Weight per gallon approximately 19 lb.

and are recorded in Table IV, where they are compared with direct determinations made in August 1947 on some of the exposed specimens at the end of the test, by means of the A.R.D. thickness meter.*

***(e)* Exposure**

The specimens were exposed outdoors in a vertical position at Birmingham on 23rd March 1937, 10 days after the completion of painting. Eighteen of the specimens were removed from test after 4·4 years' exposure, in August 1941, and two more in March 1946, after 9 years. The remaining 16 specimens were removed in March 1947, when the test was concluded after 10 years' exposure.

***(f)* Methods of Inspection**

At the earliest inspections the condition of the painting scheme was graded as follows :

0 Perfect.
1 Very good.
2 Signs of failure.
3 Marked signs of failure.

Separate estimates were made for the front and back of each specimen and the gradings were supplemented by qualitative notes on the appearance of the paint films. In addition, from June 1940 onwards, records were kept of the degree of discoloration, blistering, flaking, and rusting for each face.

(2) EXPERIMENTAL RESULTS

***(a)* Qualitative Observations**

As is invariably the case for this type of surface preparation, rapid breakdown occurred in the case of the specimens prepared for painting by weathering and hand-cleaning. Pinpoint blistering was observed beneath the paint film within the first few weeks. This was quickly followed by the development of rust-staining and ultimately by flaking and failure of the protective schemes. The areas of breakdown were associated with the boundaries between the residual mill scale and the areas from which the mill scale had been removed by weathering before painting.

At such places the mill scale is undermined by the spreading of rust and flakes off, carrying the paint film with it. Five of the 10 specimens painted in this surface condition had reached grade 3, which may be regarded as corresponding to failure, on the front surfaces after 0·9 years' exposure. The average life to this grade for all 10 specimens was 1·5 years. All the specimens in this surface condition had deteriorated to such an extent after 4·4 years' exposure that they were removed from test.

Breakdown of the painting schemes on the surfaces that had been prepared either by hot-oiling or by pickling (both methods) was much slower. Apart from surface discoloration, several of the specimens were in almost perfect condition as regards the protective efficiency of the painting scheme when the test was discontinued after 10 years' exposure. The contrast in the behaviour of painting schemes applied to weathered and to picked surfaces, respectively, may be illustrated by the photographs shown in Fig. 4.

Although the procedure of coating the specimens with oil whilst hot gave markedly superior results to those observed for the specimens that were weathered and hand-cleaned, it proved, on the whole, less satisfactory than pickling. In the case of the hot-oiled specimens isolated blisters were observed to form beneath the paint film during the first year or so of exposure. In some cases this led to local rupture of the paint film and failure. Four of the eight specimens in this surface condition were removed after 4·4 years and one after 9 years, so that only three of the specimens lasted for the full period of the test.

The explanation of the difference between hot-oiled and pickled surfaces is no doubt that the former method leaves the mill scale beneath the paint. Although the desired object of painting over a non-rusted surface is achieved, any weaknesses inherent in the mill scale itself are not eliminated, so that, if any such points of weakness exist, failure of the protective scheme may ultimately occur at them. It is also certain that the presence of mill scale beneath the paint film can be most detrimental when failure of the painting scheme has once begun, as large areas of otherwise intact paint are carried away as a result of the flaking of the mill scale. This type of failure is well illustrated by the photographs of some of the specimens prepared by hot-oiling, taken at the conclusion of the test after 10 years (*see* Fig. 5).

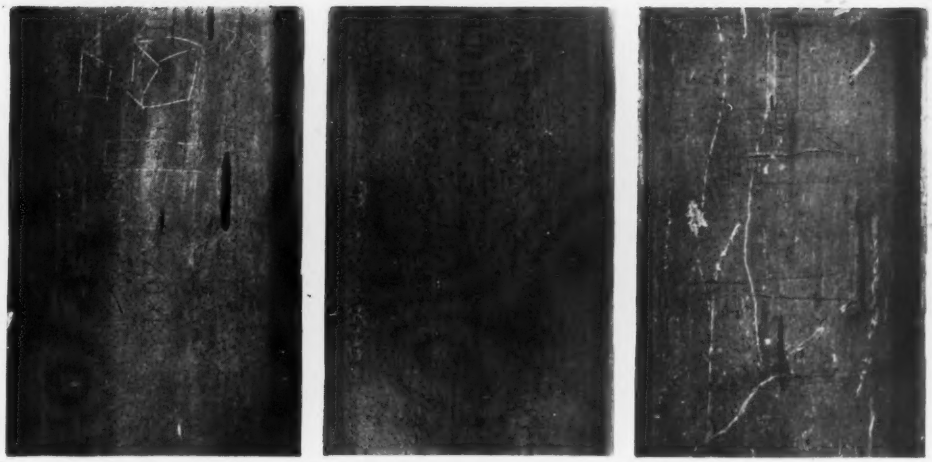
Of the various painting schemes, that comprising two coats of French grey proved by far the worst and all the specimens coated with it were removed after 4·4 years. The painting scheme consisting of two coats of red oxide paint was next to the bottom in order of merit and was inferior to the remaining three schemes. The French grey paint chalked considerably and there was little of it left after 10 years' exposure in the case where it was applied as a finishing coat over a priming coat of red lead. Otherwise, except for the fact that all the painting schemes lost their colour to some extent on prolonged exposure and that some exfoliation of the metallic lead paint film was observed, the qualitative observations made during exposure call for no further comment. The appearance of a few typical specimens after 10 years' exposure is shown in Fig. 6.

***(b)* Estimated Duration of Test to Failure**

Quantitative comparisons between the various specimens are best made on the basis of the test duration after which they were observed to reach grade 3, representing marked signs of failure ; in practice, repainting would have been desirable at this stage. As the backs of the specimens were sheltered to a considerable degree, they had not reached this point after 10 years in a number of cases, or, alternatively, when some of the specimens were removed after 4·4 years. Estimates will therefore be confined to front surfaces, which, it will be recalled, were freely exposed to the weather in a vertical position ; these estimates are given in Table V.

The main conclusion drawn from these tests is the same as that deduced from the service test, namely,

* The observed values are appreciably lower than the calculated ones. The difference may be legitimately attributed in part to wastage of the paint films themselves over the period of 10 years' exposure ; for instance the French grey had chalked considerably (*see* next col.).



Pickled in sulphuric acid | Weathered and hand-cleaned | Coated with linseed oil whilst still hot

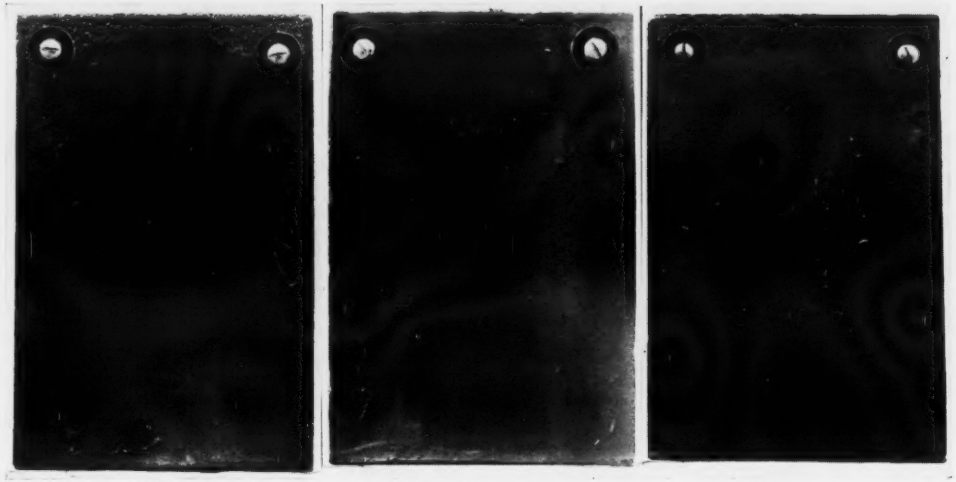
Fig. 3—Effect of surface preparation on the performance of a protective painting scheme in a service test. The 20 × 6½-in. rolled steel specimens were painted with two coats of metallic lead paint after the surface preparations shown, and were photographed in position in the gantry approximately 2¾ years after erection and the application of the second coat of paint

Weathered and hand-cleaned | Pickled in sulphuric acid

Fig. 4—Effect of surface preparation on the performance of a protective painting scheme in small-scale field tests. The 6 × 4 × ⅛-in. specimens were painted with two coats of French grey paint after the surface preparations shown. Photographed after 2·5 years' outdoor exposure at Birmingham

[*Hudson*

[*To face p.* 64



Red-lead/French-grey | Red-lead/French-grey | Metallic lead, 2 coats

Fig. 5—Failure of protective painting schemes applied to ingot-iron surfaces treated with linseed oil whilst still hot from rolling. Photographed after 10·0 years' exposure at Birmingham. The marked lifting of the paint film, to a maximum depth of 0·2 in. or so, around the boundaries of the failures will be noted, particularly near the top right corner of the right-hand photograph. This is typical of failures where the paint is applied over mill scale, and results from undermining of the latter by rust

Red-lead/micaceous iron ore | Metallic lead, 2 coats

Red-lead/French grey | Red oxide, 2 coats

Fig. 6—Condition of typical specimens after 10 years' exposure in small-scale field tests. All four painting schemes were applied to specimens pickled in sulphuric acid alone. In appraising the condition of the paint films after 10 years' exposure at Birmingham, it should be borne in mind that corresponding specimens painted after weathering and hand-cleaning had an average life to failure of 1·7 years

that a marked advantage is to be gained by the use of correct methods of surface preparation before painting. The differences due to this factor overshadow those resulting from the choice of different painting schemes, if the scheme consisting of two coats of French grey, the inferior performance of which has already been noted, is left out of account. In effect, the average life of the four main painting schemes when applied over weathered and hand-cleaned steel was 1·5 years. This was increased to $>6{\cdot}0$ years for specimens prepared by hot-oiling, to $>7{\cdot}0$ years for specimens prepared by pickling in sulphuric acid, and to $>8{\cdot}3$ years for specimens prepared by pickling in sulphuric acid followed by a phosphoric acid treatment. By way of contrast, the overall difference in the lives of the three best painting schemes, which ranged from $>6{\cdot}1$ to $>6{\cdot}8$ years, was less than 1 year. In passing, the excellent performance of the painting scheme consisting of two coats of metallic lead may be noted, as at the time these tests were initiated metallic lead was virtually a new pigment.*

It is probable that the difference between the average observed lives of the painting schemes, applied to specimens pickled in sulphuric acid alone on the one hand and pickled in sulphuric acid followed by treatment with phosphoric acid on the other, is significant. This difference, $>8{\cdot}3$ years as compared with $>7{\cdot}0$ years, is of secondary importance, however, in comparison with that between the average lives of the pickled specimens as a class and those observed on specimens prepared by weathering and hand-cleaning. A careful examination of the specimens after 10 years' test confirms the difference between the two methods of pickling deduced from the grading tables. In particular, the paint film seemed to be in much better condition at the edges in the case where the pickling was supplemented with a phosphoric acid treatment, for when 24 comparable pairs of edges were examined the paint film was found to be perfectly sound and without blemish on 13 of them in the case where phosphoric acid had been used, as compared with five in the case where it had not.

* Unfortunately, owing to the war, little additional work has been done on metallic lead pigments since 1937, and there is room for further research and development in this connection.

DISCUSSION OF RESULTS AND CONCLUSIONS

It is clear that there is a satisfactory correspondence and general agreement between the results of the service test on the crane gantry itself and of the parallel small outdoor exposure tests. Both tests agree in demonstrating once again, as has now been shown on numerous occasions by the researches of the Protective Coatings Sub-Committee, that the most vital feature for success in the protection of structural steelwork by means of paint is the correct surface preparation of the steel before it receives the priming paint coat. They show that this desirable

Table V

DURATION OF EXPOSURE TO FAILURE OF THE PAINTING SCHEMES. SMALL-SCALE FIELD TESTS

Front Surfaces, years

Painting Scheme	Surface Preparation Before Painting								
	Weathering and Hand-Cleaning		Oiling Whilst Hot		Pickling in Sulphuric Acid		Pickling in Sulphuric Acid and Phosphoric Acid		Average
I. Red-lead/micaceous-iron-ore	3·8 0·9	2·4	3·2 4·4	3·8	>10·0 6·3	>8·2	>10·0 >10·0	>10·0	>6·1
II. Red-lead/French-grey ...	0·9 1·7	1·3	8·6 10·0	9·3	7·6 6·3	7·0	9·0 9·0	9·0	>6·6
III. Metallic lead (2 coats) ...	0·9 2·0	1·5	3·2 >10·0	>6·6	8·1 >10·0	>9·1	>10·0 >10·0	>10·0	>6·8
IV. French grey (2 coats) ...	0·9 0·9	0·9	4·4 4·1	4·3	3·7 4·1	3·9	4·1 4·1	4·1	3·3
V. Red oxide (2 coats)	2·1 1·2	1·7	...		5·2 7·6	6·4	...		...
Average (schemes I to IV) ...	1·5		>6·0		>7·0		>8·3		...

efficiency of surface preparation is more readily achieved by pickling than by coating the steel with linseed oil at the mill whilst it is still hot, as is sometimes advocated. Apart from the manipulative difficulties associated with the latter procedure, which militate against its industrial use, it has the disadvantage of leaving the mill scale on the steel beneath the paint film. Under practical conditions, unless radically different types of mill scale were developed, the presence of this mill scale will ultimately lead to failure of the protective coating.

It is, however, pertinent to allude to one or two important differences between the requirements of practical construction and the procedure followed in the preparation of painted steel specimens for test on a laboratory scale. In the latter case the antecedent surface preparation of the steel and the application of each coat can be carried out under good and controlled conditions. Within reason, any desired painting schedule can be followed and ample times allowed for the drying of successive coats ; moreover, this drying can take place under cover in an atmosphere of suitably low humidity. It is undoubted that protective painting schemes applied under these conditions will protect steel adequately for considerable periods of years. Thus an ordinary two-coat painting scheme of good quality, if applied over correctly pickled steel, might be expected to have a life of from 10 to 20 years, according to the conditions of exposure. Under such circumstances the effect of correct surface preparation would be to multiply the duration of effective protection obtained from the painting scheme by, say, 5 to 10 times, as compared with the case when the same painting scheme was applied to a weathered and hand-cleaned surface.

Unfortunately, it is more difficult to achieve these ideal conditions when dealing with large tonnages of steel on a practical scale. For instance, it is doubtful whether the interval between shop painting and the application of the final coat(s) of paint on the site after erection could be controlled. Thus in the case of the present gantry the overall interval between fabrication and the final painting for individual stanchions varied from a minimum of 171 days to a maximum of 394 days, with corresponding variations in the intervals between intermediate operations.

There seems to be no reason, however, why the initial surface preparation of the steelwork and the application of the priming coat of paint should not take place immediately after fabrication under the desired good conditions. This would go far towards achieving the maximum degree of efficiency of the protective painting scheme, for, in the case of many structures, the priming coat could safely be left to protect the steel until the protective scheme was completed by the application of the final coats at the site after erection.

It also seems clear that, in order to ensure efficiency from the economic point of view, two requirements need to be met, namely :

(1) The provision of plant which would follow the fabricating shop, specially designed for descaling and painting structural steel. One can envisage a well-planned assembly of machines or apparatus for pickling, grit-blasting, spray-painting, dip-painting, and even for phosphating, stoving, and metal-spraying (*see* below).

(2) The cost of installing and maintaining such a plant could be justified only if it were kept in more or less continuous production. This could be achieved by educating the user of structural steel as to the value of correct methods of surface preparation and painting. Alternatively, until such time as the demand for these methods became universal, it should be possible, by arrangement amongst individual firms engaged in the structural-steel industry, to concentrate the production of descaled structural steelwork, at one or two centrally disposed plants, which could thus be kept running continuously.

It remains to add that a further difference between small-scale tests and the realities of practical service is the fact that the protective paints on actual structures are liable to damage and often suffer such damage, as indeed was obvious in the case of the present service trials. It is clear the effect of such damage is to reduce somewhat the advantages to be gained by correct surface preparation, as compared with the estimates deduced from small-scale exposure tests, where any damage that may occur is disregarded when assessing the results.

Nevertheless the fact remains that correct surface preparation will pay rich dividends when applied to the painting of structural steelwork. It is suggested that in cases where marked damage to the protective scheme is to be expected, the provisions for protection should go a step further and comprise a combination of a metallic coating—aluminium, lead, or zinc—with paint. Such composite protective schemes are essentially a new departure and are now being studied on a fundamental basis by the joint technical panel* of the Protective Coatings Sub-Committee with the paint and bituminous protective products industries. The practical application of these methods would involve the provision of plant for metal spraying and, possibly, electrodeposition and hot-dipping as well, at the fabricating works.

Acknowledgments

The Protective Coatings Sub-Committee wish to express their thanks to the Appleby-Frodingham Steel Co. for the provision of the test facilities described.

The author is indebted to his former colleague, Dr. T. A. Banfield, for considerable assistance with the earlier inspections and tests and more recently to Mr. J. F. Stanners for similar help. The photographs used for the illustrations were taken by Dr. Banfield and Mr. L. Eaton of the British Iron and Steel Research Association's Photographic Department.

* Joint Technical Panel JP1 (Paints for Protective Steelwork).

Plastic Replicas for Surface-Finish Measurement

By J. Pearson, Ph.D., M.Sc., F.R.I.C., and M. R. Hopkins, M.Sc., F.Inst.P.

SYNOPSIS

A method is described for the assessment of the finish of metal surfaces through the intermediary of plastic replicas, which can be examined directly on a stylus instrument. The method makes possible the examination of surfaces the location of which is such that direct measurement is difficult. These replicas may be useful for other methods of surface examination.

During recent years considerable interest has been shown in the geometrical characteristics of machined metal surfaces.[1] The development of the stylus type of surface-finish measuring instrument has made it possible to determine the shape of the profile of a surface, and at the same time to assign a numerical value to the degree of roughness of the surface, with ease and rapidity.[2]

The pick-up of a stylus instrument carries a diamond-pointed stylus having a radius of about $\frac{1}{1000}$ in. at the tip. The stylus bears very lightly on the surface and is free to move in a direction perpendicular to it, so as to follow the contour as the pick-up is moved across the work. The motion of the stylus gives rise to disturbances in an electrical system, which can be amplified and recorded on a moving paper chart, and also measured on an "average meter," which indicates the average roughness of the surface being tested.

The instrument which has been used in the work described in this paper is the "Talysurf," made by Messrs. Taylor, Taylor and Hobson, Ltd., Leicester, in which the vertical magnification of the graphical record can be varied in steps from 400 to 100,000. The horizontal magnification (*i.e.*, along the profile) is, for convenience, much less, being either 50 or 200. The records reproduced in this communication were taken at a horizontal magnification of 200. The average roughness is defined as the mean deviation of the ordinates of the profile curve.

Suppose that the irregular curve shown in Fig. 1 represents the profile of a surface. Let the line XX' be drawn parallel to the general direction of the curve, so that the areas above and below the line are equal. A more precise definition of the centre-line XX' is that it should be drawn so that the sum of the squares of the ordinates of the curve with respect to it is a minimum. If ordinates are drawn from the centre-line to the curve, the average roughness is the mean of these ordinates, irrespective of sign. The average roughness is obtained as a meter reading, the unit being 1 micro-inch (10^{-6} in.), generally written 1μ-in. This reading is a function of the frequency response of the average-meter circuit, which is designed to exclude long wavelengths so as to give useful results for surfaces which are commonly encountered in practice.

THE NEED FOR REPLICAS

Normally, specimens are brought to the Talysurf for surface-finish examination. This procedure is satisfactory when dealing with small specimens, but it is not convenient when the surfaces of large, heavy components which are not readily portable, have to be examined. It is, moreover, sometimes necessary to examine surfaces which are awkwardly located or even inaccessible to the pick-up. In order to overcome difficulties of this kind it is desirable to be able to make replicas of the surface under test, and to examine them on the Talysurf instrument. The replicas have to satisfy a number of conditions, the most important of these being fidelity of reproduction; irregularities of the order of one-millionth of an inch have to be registered without distortion. Again, the replicas must be robust, capable of withstanding a reasonable amount of handling, and hard enough not to be damaged by the Talysurf stylus, at least for one traverse. The replicas made for electron-microscope work are not suitable in this respect, being too fragile and too difficult to set up for stylus measurement. The method of preparation of the replicas

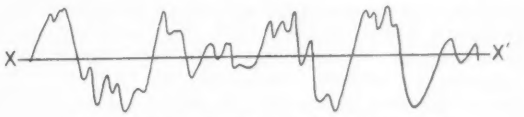


Fig. 1—Representation of surface profile

should be fairly simple, and should require only a short period of time, so as not to interfere unduly with production operations. The need for elaborate cleaning of the surface to be tested would be a disadvantage, and any method, such as that employed by Faust and Tolansky,[3] involving heating of the metal specimen, would be undesirable because of the difficulty of dealing with large masses of metal.

DEVELOPMENT OF REPLICA TECHNIQUE

Preliminary experiments with low-melting-point alloys and with dental compositions showed that these materials were unsuitable as solidification occurred on the cold metal surfaces before intimate contact had been achieved. This suggested immediately the use of a liquid organic plastic to be cured *in situ*. The plastics which can be thus employed are limited in number. Phenolics which, when cured, would be sufficiently hard, are ruled out because, in order to effect setting at a suitable rate, they require strongly reactive catalysts, which have been shown to attack many metals. The curing of urea-formaldehyde

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Dr. Pearson and Mr. Hopkins are engaged in research at the B.I.S.R.A. Laboratories, Sketty Hall, Singleton Park, Swansea.

syrups can be effected by milder reagents, but experiments showed that typical commercial materials were unsatisfactory ; adequate cure in a sufficiently short period was not found possible. Styrene is a liquid which, when polymerized, is hard enough for the purpose in view, but it was found impossible to carry out polymerization in the cold with the conventional catalysts in anything under several hours, a period which is undesirably long.

At this stage it was decided to investigate the possibility of employing methyl methacrylate, which can be polymerized at room temperature in a short period. During a visit to Imperial Chemical Industries (Plastics), Ltd., the authors were shown the technique of curing mixtures of liquid and solid methyl methacrylate by ultra-violet light. These mixtures took the form of soft doughs. When the technique was tried in these laboratories, it was found that although the material was capable of taking a good impression of a metal surface, it was not possible to guarantee accuracy, because minute air-bubbles, invisible to the naked eye, were entrapped between the dough and the metal. These bubbles could not rise through the plastic mixture because of its very high viscosity. Another disadvantage of this method of making replicas was that the plastic tended to adhere firmly to rough metal, and it was often impossible to remove it in one piece.

The disadvantage of persistent air-bubbles was overcome by using a liquid mixture of monomeric and polymeric methyl methacrylate. When this is poured over a metal surface it flows into even the smallest irregularities without entrapping air. Adhesion between the cured plastic and the metal can be reduced by the addition to the liquid of small proportions of tributyl citrate to act as a " stripping agent." In order to reduce curing time to a minimum, it is desirable to have the liquid plastic film as thin as possible ; to retain it in place on sloping surfaces and to make it more robust for subsequent handling, it may be backed with a piece of Perspex sheet.

An investigation, carried out at a strip-mill, of a problem involving the roughness of mill rolls confirmed that the technique can be successfully employed under industrial conditions, without interfering unduly with works routine.

PREPARATION OF REPLICAS

Liquid Methyl Methacrylate Mixture

To 20 ml. of monomeric methyl methacrylate, freed if necessary from stabilizer,[4] is added 0·5 ml. of tributyl citrate and 0·2 g. of benzoin (a photochemical catalyst). The mixture is warmed to 40° C. and stirred until the benzoin is dissolved. Then 3·6 g. of polymethyl methacrylate (" Diakon F granules ") are added and the whole stirred by hand until a homogeneous mixture is obtained. The mixture is allowed to stand in the dark for a few hours to allow air-bubbles to clear and is then ready for use. The liquid so obtained should be stored in a closed vessel in a cool, dark place until required. Since it polymerizes slowly of its own accord, it is advisable to make up small quantities only at a time.

This method of making the monomer-polymer mixture is preferred to that of partially polymerizing the monomer by heating with benzoyl peroxide, as employed by Brown and Jones.[4]

Perspex Sheet

Unplasticized transparent Perspex sheet, $\frac{1}{8}$ in. thick, is cut into pieces approximately 1 in. sq., and all edges are chamfered with a file. If replicas are to be made from surfaces of small radius of curvature, a strip of Perspex, 1 in. wide, is heated, bent to the required radius of curvature, and allowed to cool slowly before the squares are cut off. The slow cooling is to eliminate internal stress which may lead to subsequent cracking.

Ultra-Violet Lamp

Since the most effective wavelength for curing benzoin-catalysed methyl methacrylate is 3600 Å., care should be taken in the choice of source of ultra-violet radiation, as in some makes of mercury-vapour lamp the outer glass envelope or the actual discharge tube is made from materials which do not transmit this wavelength. The most convenient source has been found to be a B.T.H. 125-watt Mercra lamp.

Procedure

The metal surface is cleaned with a suitable organic solvent, and then with industrial methylated spirit, and allowed to dry. A drop of the monomer-polymer mixture is placed on the surface. A piece of Perspex sheet, cleaned with water and dried with a fluff-free cloth, is placed carefully thereon, and pressed down in firm contact with the metal. Excess liquid is extruded round the edges of the Perspex sheet. The ultra-violet lamp is placed 5–6 in. from the surface, and the specimen irradiated for 40–60 min. At the end of this period, the liquid has been cured, and has taken a faithful impression of the metal surface. Any identification marks may be made on the upper surface of the replica with a steel scriber before the specimen is removed. The replicas are, in general, readily lifted from the metal by inserting under one of the chamfered edges a chisel-pointed tool of wood, plastic, or soft metal (brass or aluminium), and gently levering off. The excess material around the edges of the replica can be cut away with a sharp knife.

When dealing with sloping, vertical, or under surfaces, the drop of monomer-polymer mixture is

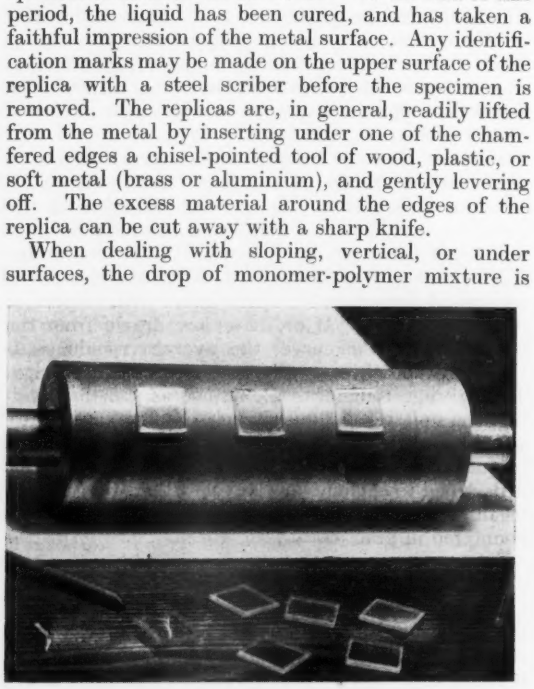

Fig. 2—Plastic replicas in position on a steel cylinder

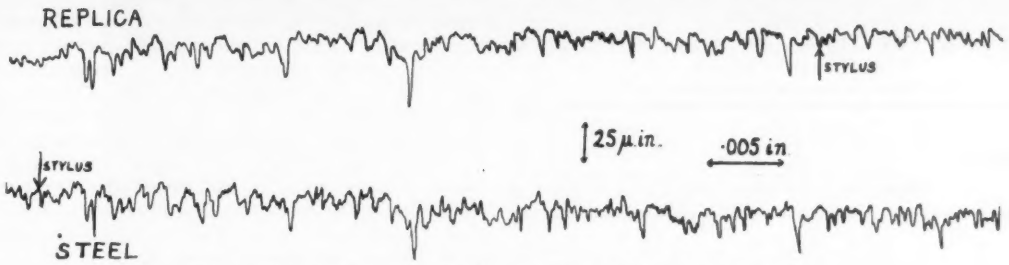

Fig. 3—Talysurf records of a ground steel surface and its replica

placed on the Perspex square, which is then pressed on in the desired position and cured. By pressing firmly in contact with the metal, it will remain in position even on vertical surfaces, provided that they are fairly rough. On smooth sloping and vertical surfaces, it is advisable to use a small " stop " of plasticine to prevent the square from sliding. Figure 2 shows replicas in position on a steel cylinder ; this is for the purpose of demonstration only, as an object of this size could obviously be dealt with directly on the Talysurf table.

The replicas are conveniently mounted on a metal slab by means of plasticine, and after levelling, may be placed directly on the Talysurf table. As polymethyl methacrylate is somewhat softer than most metals, it is advisable not to make more than one traverse of the stylus across a given part of the specimen, as this usually leads to scoring and roughening of the surface in that part. Slight inaccuracies in levelling of the specimen may be corrected on the instrument between traverses, and after racking back, the replica is displaced laterally by a small amount. A fresh area is thus brought under the stylus, and as many as fifty distinct average roughness readings (or records) may be taken on each 1-in. sq. specimen without overlapping.

Accuracy of Reproduction

To test the accuracy of reproduction, a replica was made of the surface of a ground steel specimen. A Talysurf record at a vertical magnification of 20,000 was taken on the steel, and an attempt was made to take a record on the corresponding part of the replica. The two records are shown in Fig. 3. Although the replica is a negative of the steel surface, and therefore the stylus must be applied to the opposite side of the profile, both records appear in the figure as positives. This is achieved as follows : If A and B are the beginning and end of the traverse of the stylus on the steel specimen, and A' and B' the corresponding points on the replica, the steel record is taken from A to B, while the replica record is taken from B' to A', and then turned through 180° in its own plane. In this way peaks correspond to peaks, and valleys to valleys. Records taken on the steel before the replica had been placed on it and after it had been removed, showed that no plastic had been left behind on the steel surface, nor had the steel surface been damaged in any way.

Because of the difficulty of recording exactly corresponding traverses on specimen and replica, a pair of records was taken on an etched glass standard, kindly provided by the National Physical Laboratory, and on its replica. In this case, the specimen is crossed by parallel grooves of uniform depth, so that it is not necessary to take great precautions to ensure that the specimen and replica records are taken over exactly corresponding paths. These records are shown in Fig. 4.

A rather more general indication of the accuracy of reproduction obtainable is given in Table I, which shows average roughness readings carried out on various steel surfaces and on the corresponding replicas. Approximately thirty readings were taken over each specimen and its replica without attempting to obtain exact correspondence between traverse positions.

ALTERNATIVE USES FOR REPLICAS

Microscopic Examination

In order to study further the faithfulness of the overall reproduction obtained with these replicas, it was decided to ascertain to what extent the minute irregularities on the surface of a polished and metallographically etched specimen were registered. Samples of wrought iron and cast iron were polished and etched in picral, and replicas were made from them. Corresponding areas on metal and replicas were then photographed at a magnification of 100. The metals were photographed by reflected light in the normal manner, whereas the replicas were photographed by light transmitted vertically through them,

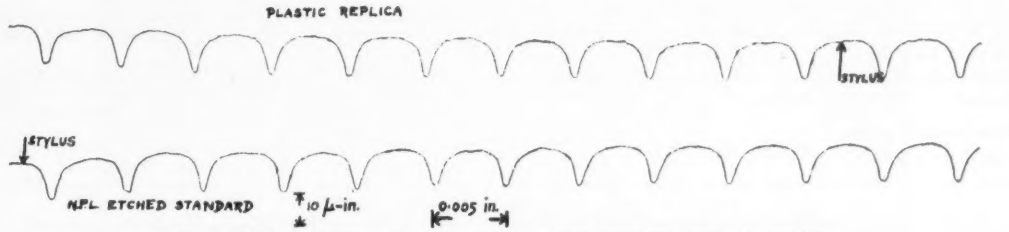

Fig. 4—Talysurf records of an etched glass standard and its replica

Table I*
AVERAGE ROUGHNESS OF STEEL SPECIMENS AND REPLICAS

The values are given in micro-inches (10^{-6} in.)

Specimen	Steel		Replica	
	Average Roughness	Standard Deviation	Average Roughness	Standard Deviation
1	2·81	0·14	2·81	0·22
2	13·2	1·1	13·5	1·1
3	17·2	0·9	17·2	0·9
4	107·4	7·3	101·4	7·4
5	147	25	146	31
6	195	44	189	41

the light passing from the plane to the roughened face. The photographs of the replicas are, of course, mirror images of those of the metals; inspection of Figs. 5, 6, and 7 shows the extent to which the surface characteristics of the metal are reproduced in the replica.

In view of the quality of reproduction obtained at a magnification of 100, it was decided to carry out an examination at a higher magnification. Figure 8 is a photograph (× 700) of an etched cast iron, and Figs. 9 (*a*) and 9 (*b*) are similar, though not corresponding, photographs of the replica. The fine metallographic detail is well reproduced.

It is suggested that plastic replicas prepared by the method described above would prove of value in the study of objects the size or location of which precludes their being examined *in situ*, particularly when cutting out of specimens is prohibited. Examples which come to mind are the metallographic study of the structure of mill rolls as revealed by suitable etching of the polished surfaces, and the examination of corroded surfaces by metallographic methods, or by other methods which enable a quantitative estimate to be made of the extent of corrosion pitting.

Projection Transparencies

If the replicas are mounted in a suitable holder, or, alternatively, are made with an appropriate-sized piece of Perspex, they make excellent transparencies for projection by means of a lantern. This makes the replicas of value for demonstrating surface finish to several people at the same time. They may also serve as examples of standard surface finish with which to compare current production, but it should be borne in mind that the picture obtained is only of the overall character of the surface, no indication being given as to the depth of irregularities.

Multiple-Beam Interferometry

Since the upper surfaces of flat replicas are plane and essentially parallel to the lower surfaces, it is possible that they could be employed for multiple-beam interferometry by the methods devised by Tolansky and his co-workers.[3]

Electron Microscopy

Brown and Jones[4] have described a method of using methyl methacrylate as an intermediary in the preparation of silica replicas for electron-microscopic examination. Partially polymerized methyl methacrylate, containing benzoyl peroxide, is poured over the surface to be studied, and allowed to set spontaneously. The plastic film is removed, coated with silica, and then dissolved away in toluene, thus leaving a silica replica. It would appear that the whole process could be considerably expedited by employing the monomer-polymer mixture as described above, made up with less Diakon if a lower viscosity were desired, and curing by sunlight or ultra-violet radiation.

Where it is not desired to use silica coatings, but to examine the plastic replica directly, it is possible that a specimen could be coated with a solution of the monomer-polymer mixture in a volatile solvent, allowed to dry (as is done with Formvar replicas) and the polymerization completed under ultra-violet light. The thin film could then be removed, mounted, and examined in the manner usual with other plastic replicas.

* Table I has been published previously in a preliminary communication.[5]

CONCLUSIONS

A procedure is now available which considerably extends the applicability of stylus methods of assessing surface finish. Objects, the size or location of which is such that direct measurement by such means is not feasible, can now be readily examined, provided that an ultra-violet lamp can be used to irradiate the surface.

The use of replicas made by the method described is not confined to stylus instruments only. They are quite suitable for microscopic examination, and with suitable mounting can be used as projection transparencies. It is possible that they could be used for interferometric studies and there seems no reason why the technique of curing monomer-polymer mixtures by ultra-violet light should not considerably speed up the preparation of silica replicas for electron microscopy.

Acknowledgments

The authors are indebted to Imperial Chemical Industries (Plastics), Ltd., for their advice, practical assistance, and supply of materials used for preparing replicas. Thanks are due to Sir Charles Goodeve, F.R.S., Director, and to Mr. D. Luther Phillips, Head of the Swansea Laboratories, of the British Iron and Steel Research Association, for help and suggestions, and to Mr. J. P. Riddle for taking the Talysurf measurements.

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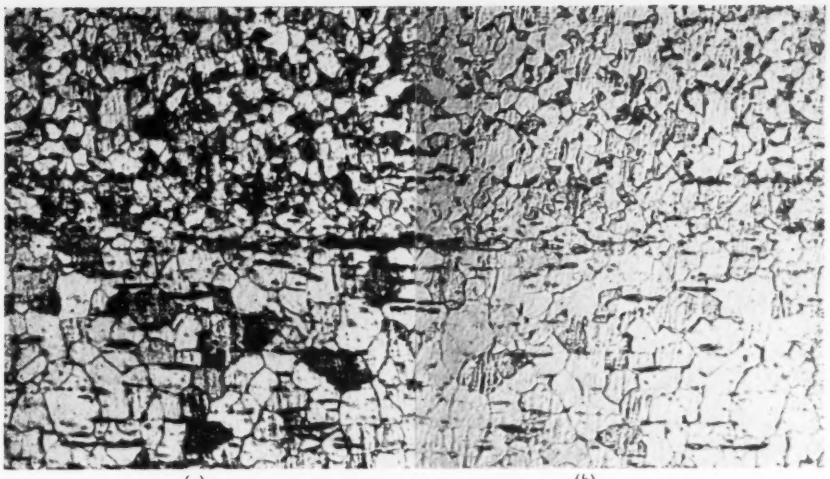
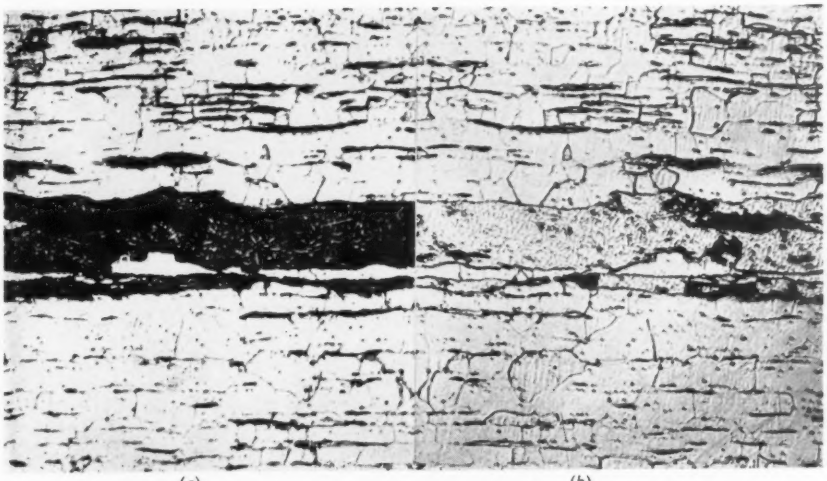


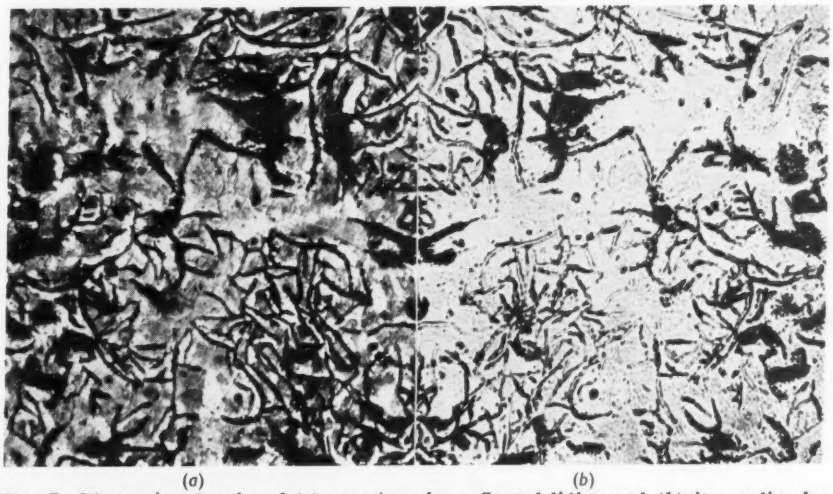
(*a*) (*b*)

Fig. 5—Photomicrographs of (*a*) wrought iron by reflected light, and (*b*) its replica by transmitted light × 100



(*a*) (*b*)

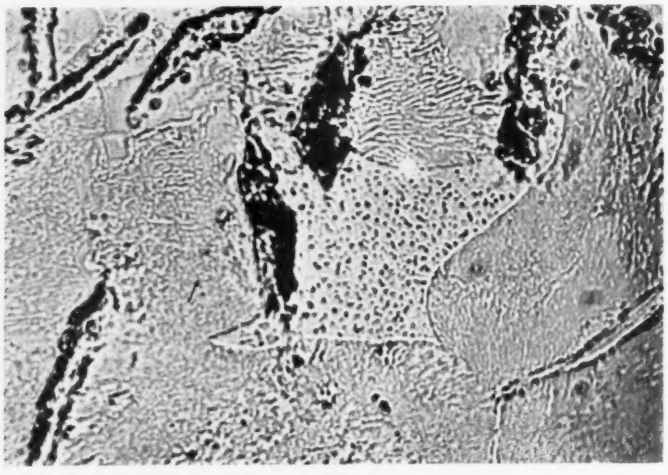
Fig. 6—Photomicrographs of (*a*) wrought iron by reflected light, and (*b*) its replica by transmitted light × 100



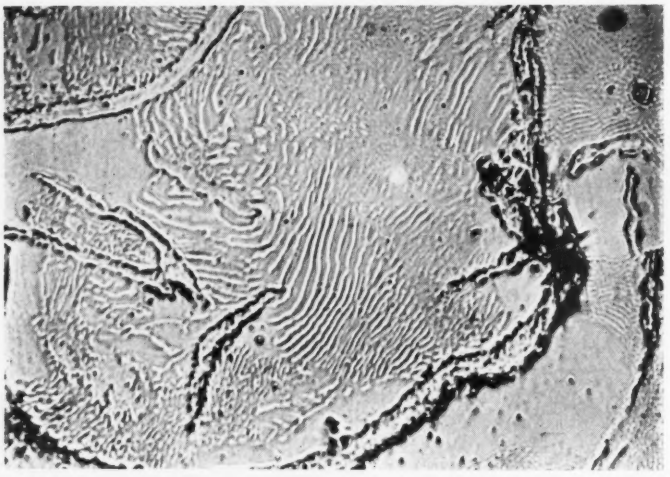
(*a*) (*b*)

Fig. 7—Photomicrographs of (*a*) cast iron by reflected light, and (*b*) its replica by transmitted light × 100

Fig. 8—Photomicrograph of cast iron, showing eutectic and pearlite × 700



(*a*)



(*b*)

Figs. 9 (*a*) and (*b*)—Photomicrographs of replicas of cast iron × 700

DISCUSSION ON PAPERS

DISCUSSION AT MEETINGS · WRITTEN CONTRIBUTIONS

Correspondence on the Paper—

THE EVOLUTION AND ABSORPTION OF HYDROGEN BY STEEL IN INDUSTRIAL REHEATING FURNACES* *by J. Cameron*

Dr. **C. A. Zapffe** wrote: Dr. Cameron has chosen a topic of undoubted importance, and he has treated it with marked care.

However, the present writer has noted before, with some surprise, that the publications of the Hair-Line Crack Sub-Committee give little or no attention to the score or more of contemporaneous American publications on the subject of hair-line cracks and related phenomena of hydrogen embrittlement.

For example, Dr. Cameron initiates his discussion with the remark that "the exact mechanism has not been fully elucidated." The present writer submits that the mechanism and many of its related phenomena *have* been elucidated, at least well beyond the background assumed in Dr. Cameron's and other writings. Eight years ago[1] the concept was proposed which has since been termed the "planar-pressure theory." It was carefully described for hair-line cracks,[2, 3] where embrittlement consummates in cracking; for the numerous kindred phenomena in forgings, welds, and castings—"fish eyes," "white spots," etc.—which represent the stage preliminary to cracking;[4, 5, 6, 7] and for the general phenomenon of hydrogen embrittlement.[8, 9, 10, 11, 12, etc.] In 1943 the microscopic behaviour of the occluded gas was studied using a new technique;[13] and in 1946, the "planar-pressure theory" was described and demonstrated.[14]

Briefly, the gas occludes under conditions of high pressure throughout the same imperfection structure of the crystal which seats both mechanical deformation and other precipitation phenomena. When this pressure surpasses a critical value slip is immobilized; and the zone under consideration is embrittled. In the absence of superimposed stress on this area, the condition is that of the "fish eye" or "white spot." When sufficient stress is superimposed, as through thermal and transformational means, the zone cracks to accommodate the stress, and the condition of hair-lines results. The gas itself, operating in this intrinsic void structure, has never been known to cause a crack without superimposed stress. It only causes embrittlement. It is, therefore, wrong to blame the crack solely upon hydrogen pressure. Annealed or stainless metal will not crack regardless of hydrogen pressure. Further details of the mechanism can be found in the appended references, and in other references to which they in turn refer. They account satisfactorily for all observations made to date on hair-lines, including the "lower limiting concentration," which would logically follow from residual occlusion at subcritical pressure.

As for the theory of absorption from environmental gas, here again the previous concept is not only adequate but it exposes a weakness in the present diagnosis. The fact that absorption is proportional to the square root of P_{H_2} designates atomic H to be the species upon which absorption depends, not upon H_2. If CH_4 were the environmental gas, absorption of H would depend upon a fourth root, and so with other gaseous carriers of H. Perhaps the point is made clearer by calling attention to the great absorption following from acid or cathodic pickling, where P_{H_2} is obviously too indirect in its relationship to be useful at all. Instead, P_H must be considered.

This Dr. Cameron begins to do in his discussion of scaling reactions from H_2O. But in the riveted steam boiler, for example, where caustic substances concentrate in riveted seams, the hydrogen activity at that site is quite unrelated to either the H_2 or the H_2O content of the boiler. The absorption of hydrogen by the steel depends solely upon the surface activity of atomic hydrogen at that site, just as it does in pickling. These activities may reach proportions *corresponding* to extremely high pressures of H_2, as explained in a recent paper.[15]

While Dr. Cameron's calculations are satisfactory for heating a *fully and continuously scaled* ingot, three weaknesses appear which might become the controlling factors in the issue upon which his study is based. First, there is the likelihood that steam will contact free metal at some stage in heating, either in the early stages of heating, or at localized areas

* *Journal of The Iron and Steel Institute*, 1947, vol. 157, Dec., pp. 609–615.

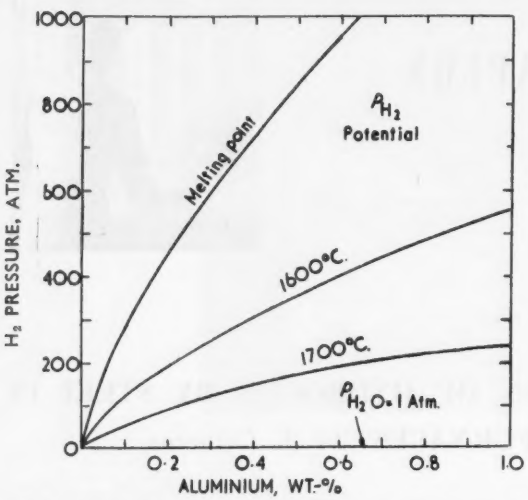


Fig. A—Hydrogen activity calculated on the basis of equivalent pressures of H_2 for aluminium-containing steel contacting H_2O at 1 atm.[15]

during heating when the scale spalls or cracks to allow penetration of furnace gases. Second, upon such contact the initial activity of the released hydrogen is determined, not by the equilibria he discusses, with free oxide present, but instead by the thermodynamic values of the particular metal. For deoxidized or alloyed steels these values can become very great, as indicated in the accompanying illustration, Fig. A, calculated for steels containing aluminium. Not fractions of atmospheres, but hundreds of atmospheres are the order. Whilst the temperature range in that Figure concerns molten steel, the "hydrogen potential" *increases* with decreasing temperature. Lastly, once the gas enters the steel its conditions for effusion are considerably modified by the fact that it effuses at the inner scale layer, where equilibria are of the order of those dismissed, in his paper, for absorption, and can be considerably changed by *in situ* entrapment of much higher values for P_{H_2O} than he considers.

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AUTHOR'S REPLY

Dr. **J. Cameron,** in reply, wrote : The author welcomes Dr. Zapffe's contribution and has found it of great interest. Although they have not been specifically mentioned he is, of course, aware of the valuable contributions to the theory of hair-line crack formation made by Dr. Zapffe and his colleagues in America. Until, however, these ideas have been universally accepted it is still true to say that the exact mechanism of hair-line crack formation has not been fully elucidated. Dr. Zapffe is correct in saying that it is the pressure of atomic hydrogen which is important for hydrogen absorption. Since, in the case considered in the paper, the atomic hydrogen is in equilibrium with molecular hydrogen according to the reaction :

$$H_2 \rightleftharpoons 2H,$$

it is quite permissible to consider the square root of the pressure of molecular hydrogen, since, of course, these are connected by the relation :

$$\frac{p_H^2}{p_{H_2}} = K.$$

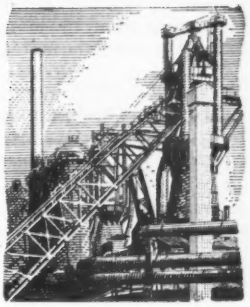
Such a simple relationship does not hold, as Dr. Zapffe points out, for processes such as pickling, caustic embrittlement, and other cases where atomic hydrogen is liberated on the surface of the steel. It should be pointed out, however, that the paper does not profess to deal with such cases, but is limited to the absorption from furnace atmospheres.

With regard to the possibility of steam coming into contact with bare metal, the author is of the opinion that such a possibility can be neglected. Most ingots are already coated with oxide before charging into a reheating furnace, and the surface area exposed through cracks and the times of such exposures will be so small as to render any appreciable hydrogen absorption negligible.

The effect of alloying elements such as aluminium in the steel would be as Dr. Zapffe indicates, provided the atmosphere is in equilibrium with steel of that surface composition. However, the concentration of aluminium at the surface will be rapidly reduced by preferential oxidation to the value at which the hydrogen potential is the same as for iron. The mere fact that the scale on the steel consists of wüstite and Fe_3O_4 is sufficient guarantee that that is true, and that the equilibrium which the author considers in the paper is in fact the important one.

IRON AND STEELWORKS ENGINEERING

THE IRON AND STEEL ENGINEERS GROUP



DESCRIPTION OF NEW PLANT

The Ore-Preparation Plant at the Workington Branch of The United Steel Companies, Ltd.

THE blast-furnaces at Workington operate with a burden consisting of approximately 80% foreign and 20% local hematite ores. During the war, when supplies of certain foreign ores were in jeopardy, it was deemed necessary to make arrangements to utilize available stocks of fine ores; the sintering plant was therefore installed, erection being completed in 1943.

After commissioning the sintering plant it was decided, in order to produce a fully graded burden for the blast-furnaces, to lay down a crushing and screening plant. This installation was completed early in 1947.

In addition to the anticipated benefits, which have all been fully realized, certain others have also been derived, the most important of which is perhaps the elimination of sulphur from the local ores during sintering.

THE CRUSHING AND SCREENING PLANT

The incoming ore is discharged from the waggons by a 40-ton tippler into an underground hopper from whence it is delivered by a 36-in. wide conveyor belt either to the primary crusher house or, in the case of ores already crushed, to the ore-stocking ground (*see* Fig. 1).

Grizzly and Primary Crusher

The ore delivered to the primary crusher house is transferred to a 42-in. wide feeder conveyor leading to the grizzly. The grizzly is a five-shaft live-roll machine with rolls 15 in. in dia. and 42 in. wide. The apertures in the grizzly rolls are 3 in. wide, with the result that the + 3-in. material passes over to the crusher, whilst the — 3-in. material falls between the rolls to by-pass the primary crusher, the two materials ultimately joining on a common belt delivering to an underground concrete hopper. Ores too small to warrant passing through the primary crusher may be diverted direct down a chute into the concrete hopper.

The primary crusher is of the Blake jaw-type,

Manuscript received 26th January, 1948.

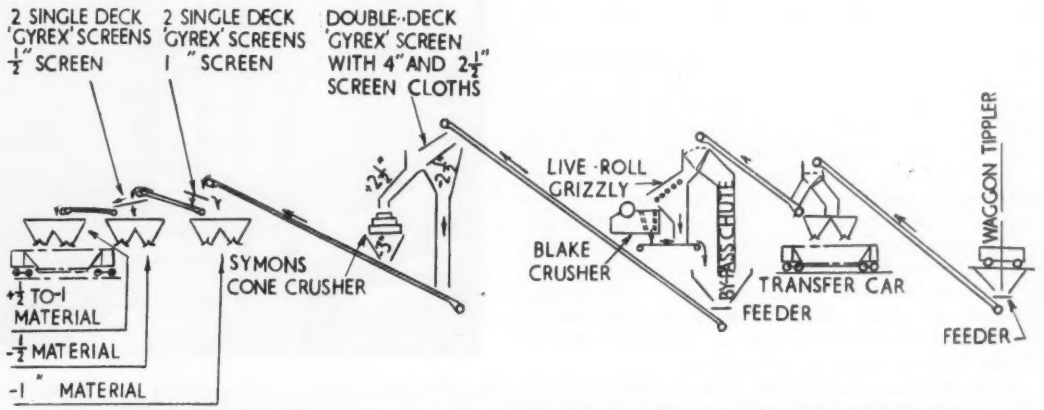


Fig. 1—Diagrammatic layout of ore crusher and screening plant, showing flow of material

measuring 48 in. by 36 in., and is driven by a 150-h.p., 735-r.p.m. electric motor through V belts.

Secondary Crusher

From the underground hopper the crushed and by-passed materials are delivered by a 36-in. wide conveyor belt to the secondary crusher house. Here the ore falls on to a 60-in. by 144-in. Gyrex screen which, although double-decked, acts in fact as a single screen since the oversize material from both

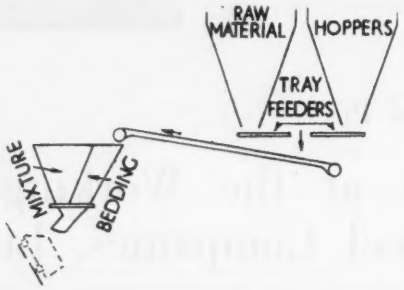


Fig. 2—Flow diagram of bedding material

decks joins on entering the secondary crusher. It will be realized therefore that the top deck, which contains a 4-in. screen, serves merely to increase the efficiency of the bottom deck, which contains a 2½-in. screen.

The oversize, *i.e.*, the + 2½-in. material, is crushed by a 5½-ft. Symons cone crusher, driven through V belts by a 200-h.p., 738-r.p.m. electric motor, whilst the undersize by-passes this crusher to join the crushed material on a common 36-in. wide belt running at 300 ft./min. which leads to the screening house.

Screening House to Storage Bunkers

From this belt the ore is delivered through a bifurcated chute to the first two single-deck Gyrex screens (measuring 48 in. by 120 in.) which are in parallel and contain 1-in.-mesh cloths. The oversize material from these screens, *i.e.*, the + 1- to — 2½-in., is delivered by chutes into a storage bunker, from which it is drawn either for despatch to the stocking ground or to the blast-furnace bunkers direct. The — 1-in. material, having passed through the first pair of screens, is taken by two 24-in. wide belt conveyors running at 250 ft./min. to the second two screens which are similar in all respects to the first except that they are fitted with ½-in. mesh cloths. The oversize from these screens, *i.e.*, the + ½-in. to — 1-in. material which constitutes the bedding for sintering, is delivered by two 24-in. wide conveyors running at 200 ft./min. to a second storage bunker, whilst the undersize, *i.e.*, the — ½-in. material which constitutes the fines for sintering, is delivered through a chute to a third storage bunker. The storage bunkers, the doors of which are power-operated by compressed-air cylinders, have a designed capacity of 120 tons for each size of material.

Delivery from each of the three bunkers is direct into a 60-tons capacity transfer car which carries the materials either to the stocking ground or to the blast-furnace bunkers as required.

The designed capacity of the crushing and screening plant is 300 tons/hr.

THE SINTERING PLANT

The sintering plant, which is of the Greenawalt type, was originally installed to deal with imported fines, but with the addition of the ore-crushing and screening plant sufficient fines became available to meet the demands for sinter without resorting to the importation of fines as such.

Storage Bunkers to Mixer

The + ½-in. to — 1-in. bedding and the — ½-in. fines from the screening-house storage bunkers are transferred to the stocking ground from whence they are lifted by the 12-ton ore-bridge crane ; the former are deposited into two bunkers situated at the side of the sintering plant, and the latter into bays alongside the sintering-plant feeder silos. The — ½-in. (of which approximately 65% is — ⅛-in.) coke breeze from the coke ovens is delivered in hopper waggons and dumped into bays adjacent to those already mentioned.

As and when required the fines and coke breeze are picked up by the bridge crane and placed in their respective silos, whilst the bedding is delivered to an 18-in. wide conveyor belt by means of two electrically driven push-plate feeders. This conveyor belt is driven by a 5-h.p. motor, it has a carrying capacity of 20 tons/hr., and conveys the bedding to a hopper situated below the mixer (*see* Fig. 2). The bottom outlets from the silos, of which there are six, each having a capacity of slightly over 2000 cu. ft., are 4 ft. in dia. and lead on to 6-ft. 6-in. feeder tables which in turn deliver the material at the required rate to a 24-in. wide conveyor belt (*see* Fig. 3). This belt is driven by a 7½-h.p. motor and has a carrying capacity of 150 tons/hr. The feeder tables, with the exception of that for the coke breeze, are driven through a common-drive shaft by a 40-h.p. motor.

Fig. 3—Coke breeze and fines silos with feeder tables and conveyor belt

Fig. 4—The mixer

In the case of the coke-breeze feeder table the drive is by an independent 7½-h.p. motor.

The raw materials are passed by the above-mentioned belt to another 24-in. wide belt which then delivers them *via* an inlet chute to the mixer (*see* Fig. 4).

Mixer

The mixer consists of a mild-steel drum, 26 ft. long and 5 ft. in internal dia., mounted at an angle of 1 in 12 on roller bearings and driven by a 40-h.p. motor through pinion and spur gears at a speed of 18 r.p.m. Inside the mixer are a series of blades which reduce the speed of travel of the material, consequently ensuring thorough mixing. The required moisture is added to the material by means of a spray within the mixer, after which the material is fed into a hopper located alongside that containing the bedding. In order to prevent the material from packing too tightly in the hopper the mixer is perforated at the discharge end with 3-in. dia. holes which allow a steady fall of the material.

Sintering

The bedding and mixture hoppers, which are fitted with automatic slide valves and self loaders, pass the materials for sintering into two 3-tons capacity skips. These skips are raised by an automatically controlled hoist driven by a 60-h.p. motor to the top of the plant, where they discharge into a distributing funnel leading to the bedding and mixture storage bunkers respectively. From these storage bunkers the material is fed through adjustable outlet gates into the charging car. A flow diagram is shown in Fig. 5. The charging car, driven by a variable-speed 20-h.p. motor, contains separate hoppers for the mixture and bedding which feed the sintering pans through a cut-off slide, adjustable gate, and power-driven feed roller designed to give a continuous discharge as the car passes over the pans. The feed is started and stopped by means of a guide rail, running alongside each of the two pans, which trips the feed-regulating gates and feed rollers of the two hoppers; thus, during a single run over a pan, both bedding and mixture are dropped into position. A fluffing roller positioned below the mixture outlet breaks up the flow of the material, so giving a porous charge to the pans.

The charge is ignited by means of an electrically driven ignition car running on the same rails as the charging car (*see* Fig. 6). The ignition car consists essentially of a hood lined with cast-iron protection

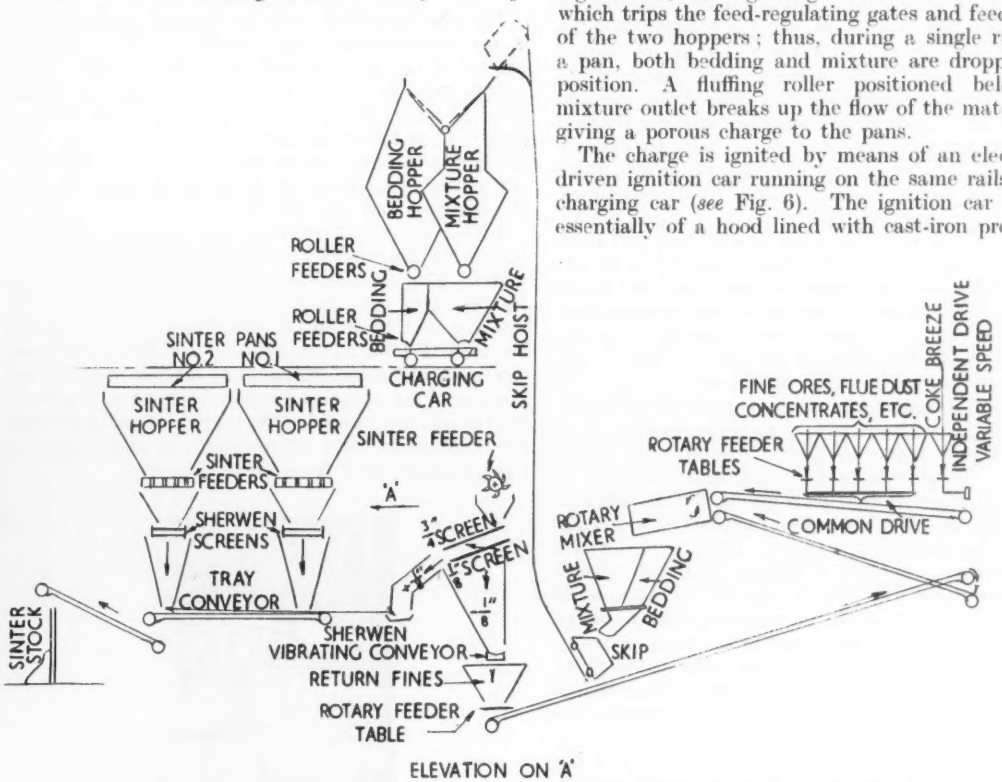


Fig. 5—Diagrammatic layout of sintering plant, showing flow of materials

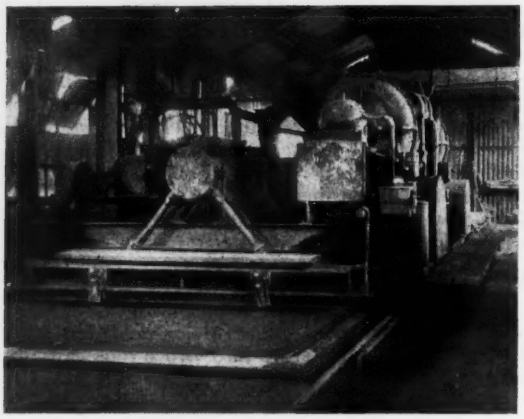


Fig. 6—Ignition car approaching a charged pan

plates and a sealing plate mounted on a chassis. The object of the sealing frame is to seal the hood when in position over a pan. A steel header running along the length of the hood feeds into pipes at the ends of which are the burners. Blast-furnace gas and air are supplied through two pre-mix fans, each having a capacity of 3200 cu. ft./min. at a pressure of 12 in. water gauge, to stand pipes located alongside each pan. The hood of the ignition car is connected to the stand pipes by a quick-acting coupling. When a charge is to be ignited the pre-mix fans are started and the hood is connected to the appropriate stand pipe. Then the supply valve is opened, the gas and air mixture is ignited by means of electric resistance coils, and the valves to the exhaust fans are opened. Ignition of the charge is initiated by the burning gases in about 1½–2 min., when the car is disconnected from the gas supply and moved to one end of the plant.

Each of the two pans is 22 ft. 8 in. long and 10 ft. wide, the depth being adjustable from 12 to 16 in., depending upon the nature of the material to be sintered. The hematite-iron grate bars are supported in rocking cast-steel grate frames bolted to guides running across the bottom of the pans. When a pan is in its normal position the grate bars are kept level by counter weights, but when it is tilted to empty, alternate bars drop down, thereby clearing any material that tends to stick to them. The space between the bottom of each pan and the grate is connected through hollow trunnions to an exhaust fan which provides the suction required for sintering. These exhaust fans, driven by a 460-h.p. motor and each having a capacity of 25,000 cu. ft. of exhaust gases per minute at 300° F., produce a vacuum of 50 in. water gauge at the normal temperature of the gases. The fans are connected to the pans by heavy steel-plate pipes through cyclone dust-catchers to protect them from wear by abrasion. The exhaust gases themselves are discharged into a common flue and thence to a 130-ft. high chimney.

The pans are tilted by a 20-h.p. motor and the finished material falls into a hopper located immediately below each pan.

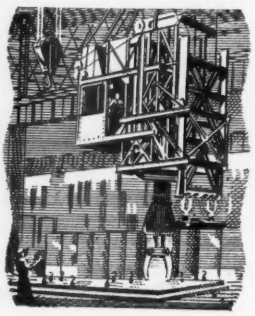
Sinter Feeders and Screens

At the discharge end of each hopper is a sinter feeder consisting of cast-steel arms mounted on a shaft driven through spur gears by a 10-h.p. motor. These feeders, in addition to breaking up the larger lumps of sinter, provide a steady flow of material to the screens situated beneath them, the latter being employed essentially to remove the fines from the sinter. The screens are electrically vibrated and have two decks.; the upper deck screens-out the $-\frac{3}{4}$-in. material, and the lower one screens-out from this the $-\frac{1}{8}$-in. material. The oversize from each of the two decks, *i.e.*, the $+\frac{1}{8}$-in., is fed down enclosed chutes on to a 24-in. wide steel-tray belt driven by a 7½-h.p. motor, whilst the undersize material, *i.e.*, the $-\frac{1}{8}$-in. (referred to as the "return fines"), together with the dust from the cyclones, falls into a receiving hopper. After cooling by water from electro-magnetically operated sprays, the return fines are delivered *via* a feeder table on to a 18-in. wide rubber belt which transfers them to a second belt of the same width and running at right-angles to the first belt. This second belt conveys the return fines to a chute which in turn delivers them into the inlet end of the mixer preparatory to mixing for re-sintering. The finished sinter, *i.e.*, the cooled $+\frac{1}{8}$-in. material, having been cooled by water sprays, is delivered by the tray belt on to a 24-in. wide inclined rubber belt which then delivers it to the stocking ground.

CONCLUSION

The plant as a whole may be said to give satisfaction in its present form, but in order to afford greater control of the mixture and hence of the final sinter composition, it is proposed to instal at the end of the silos an additional silo for dealing with the return fines. Thus the return fines will be delivered to this silo instead of direct to the mixer, and from here they will be fed *via* a feeder table on to the same belt as the fine ores and coke breeze.

Under normal conditions, the average sintering time is 20 min. which allows of an output of approximately 250 tons of sinter in an 8-hr. shift, or 150,000 tons per annum, allowing for two-shift working and time off for plant cleaning and maintenance. Whilst this production is sufficient to meet the needs of the two furnaces at present in blast, the housing of the plant has been so designed as to permit the installation of up to a further three units without interruption to the existing plant, in case a greater output should ever be required.



JOHN WATSON JENKIN, Ph.D., B.Sc., A.R.I.C., F.I.M.

JOHN WATSON JENKIN was born at St. Austell, Cornwall, in 1899, and educated at St. Austell County School, at King's College, University of London, where he graduated B.Sc. with Honours in Chemistry in 1921, and at the University of Sheffield, where he was awarded that University's first Ph.D. in metallurgy in 1923.

After serving with H.M. Forces from 1917 to 1919, Dr. Jenkin was with the Metallurgy Department, National Physical Laboratory, during the years 1923-29 before being appointed Director of Research, Tube Investments, Ltd., Birmingham. He was Adviser on Steel Tubes to the Ministry of Supply from 1941 to 1944. On the establishment by Tube Investments, Ltd., of a Department of Development and Research in 1947 he was appointed its General Manager ; he is now in charge of a large organization covering mechanical and electrical engineering and chemistry as well as metallurgy. He is the author of various papers and articles, relating more particularly to steel tubes.

Dr. Jenkin is a Founder Fellow of the Institution of Metallurgists ; he was a Member of its first Council during the years 1945-1946, and was elected President in 1946. A Member of Council of the British Iron and Steel Research Association, Dr. Jenkin has also served on the Metallurgy Divisional Panel ; he is a member of the Alloy Steels Research Committee, the Corrosion Committee, the Sub-Committee on Corrosion by Industrial Waters, of which he is Chairman, and the Sub-Committee on Soil Corrosion. He was a Member of the first Council of the British Welding Research Association, 1945-46, and served on its Research Board from 1946 to 1947; he is a member of its Main Ferrous Metals Research Committee and of the Committee on the Physical Metallurgy of Alloy Steel Welding. He is a member of the Institute of Fuel, the Electrodepositors' Technical Society, the American Institution of Mining and Metallurgical Engineers, and the American Society for Metals. In addition, he is a member of the following : the Joint Committee on National Certificates in Metallurgy ; the City and Guilds of London Institute's Advisory and Moderating Committees in Metallurgy ; the British Electrical and Allied Industries Research Association's Committee on Steels for High Temperatures and Pressures ; and various committees of the British Standards Institution. He was President of the Birmingham Metallurgical Society in 1945-46, and has been Honorary Treasurer to the Co-ordinating Committee of the Midland Metallurgical Societies since 1934. He served for many years on the City of Birmingham Education Committee's Advisory Committee on Metallurgy.

Dr. Jenkin joined the Institute of Metals in 1922 ; he was Honorary Secretary of the Birmingham Local Section from 1932 to 1938, and Chairman from 1939 to 1940. He became a Member of The Iron and Steel Institute in 1932 and was elected a Member of Council in 1946.

Elliot and Fry

Dr. J. W. Jenkin, Ph.D., B.Sc., A.R.I.C., F.I.M.
Member of Council

N E W S

ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE
Annual General Meeting, 1948

The Annual General Meeting of the Institute was held on Wednesday and Thursday, 5th and 6th May, 1948, in the Lecture Hall of the Royal Institution of Chartered Surveyors, 12, Great George Street, London, S.W.1. The sessions on the Wednesday started at 9.45 A.M. and at 2.30 P.M. and that on the Thursday, at 9.30 A.M. Dr. C. H. Desch, F.R.S., retiring President, was in the Chair during the first part of the proceedings, his place being afterwards taken by Sir Andrew McCance, D.Sc., F.R.S., the new President.

Members' Luncheon

A Luncheon was held at the Dorchester Hotel, Park Lane, London, W.1, on Thursday, 6th May, 1948. Sir Andrew McCance, D.Sc., F.R.S., President of the Institute, was in the Chair, and some 600 Members and Guests were present.

The loyal toast having been honoured, Sir Oliver Franks, K.C.B., C.B.E., Ambassador designate to U.S.A., proposed the toast of: "*The Iron and Steel Institute and the Iron and Steel Industry*," to which the Right Honourable Lord Clydesmuir, P.C., G.C.I.E., replied. The toast of "*The Guests*" was proposed by Lieut.-Colonel Sir John Greenly, K.C.M.G., Honorary Member of Council, and the President, Sir Andrew McCance, D.Sc., F.R.S., replied.

Third Hatfield Memorial Lecture

Dr. Robert F. Mehl (Carnegie Institute of Technology, Pittsburgh, Pa., U.S.A.) presented the Third Hatfield Memorial Lecture, on "*The Decomposition of Austenite by Nucleation and Growth Processes*," on Wednesday, 5th May, 1948, at 8.30 P.M., in the Lecture Hall of the Royal Institution of Chartered Surveyors, 12, Great George Street, London, S.W.1.

A full report of the proceedings at the Meeting and the text of the Third Hatfield Memorial Lecture, will be printed in a later issue of the *Journal*.

Protection of Steel against Atmospheric Corrosion and Marine Fouling

A Joint Meeting of The Iron and Steel Institute and the British Iron and Steel Research Association, to discuss several papers dealing with the protection of steel against atmospheric corrosion and marine fouling, will be held at 4, Grosvenor Gardens, London, S.W.1, on Thursday, 17th June, 1948. There will be two sessions, at 10.30 A.M. and at 2.15 P.M. Full details of the papers to be presented and discussed will be found in the April, 1948, issue of the *Journal*.

Joint Committee on Metallurgical Education

The Joint Committee on Metallurgical Education has published a pamphlet presenting its views and recommendations on "*Qualifications for Entrance to University Schools of Metallurgy*." The Joint Committee deplores the specialization to which students too often are subjected during their final years at school in order to satisfy University entrance requirements; it feels strongly that both Universities and schools should be prepared to provide a broader education without depriving a student of adequate opportunity to develop in those subjects in which he is most interested, and puts forward its suggestions for broadening the entrance examinations.

While appreciating that it is fitted to express an effective opinion only in regard to metallurgical education, the Joint Committee believes its views on this subject may well be equally applicable to the education of students of other applied sciences, and possibly also to pure scientists.

Copies of the pamphlet may be obtained from the Secretary of the Joint Committee on Metallurgical Education, 4, Grosvenor Gardens, London, S.W.1.

Selling Prices of Special Reports

As from 1st May, 1948, the prices of Special Reports of The Iron and Steel Institute will be as follows:

	Published Price	Rate to Members	Rate to Libraries and Technical Societies
Large reports ...	£1 5*s.* 0*d.*	15*s.* 0*d.*	£1 0*s.* 0*d.*
Medium reports	15*s.* 0*d.*	7*s.* 6*d.*	12*s.* 6*d.*
Small reports ...	7*s.* 6*d.*	3*s.* 9*d.*	6*s.* 3*d.*

Reprints

Separate reprints of papers published in the *Journal of The Iron and Steel Institute* since 31st December, 1946, will no longer be on sale.

Dr. J. W. Jenkin

It is regretted that the biography of Dr. J. W. Jenkin which appeared in the issue for March, 1948, is incorrect in various particulars. An amended biography and another frontispiece are therefore included with this issue and should be substituted for those which appeared in March when the monthly Journals are sent for binding.

Seventy-Five Years Ago

Siemens realized that a direct process of producing iron and steel (*see* " Seventy-Five Years Ago," on page 522 of the April, 1948, issue of the *Journal*), must be a self-acting or mechanical one, and in 1870–71 his attention again reverted to the rotating furnace. He was confident that this process would succeed provided that a lining could be developed capable of resisting the intense heat required for the precipitation of the iron, and also the chemical action. Bauxite had previously been suggested to Siemens by M. Le Chatellier, but difficulty had been experienced in putting it into a compact form and in rendering it sufficiently infusible. Further experiments, however, proved that a satisfactory lining material could be produced by binding previously calcined bauxite powder with 3% of argillaceous clay and adding to this mixture 6% of plumbago powder to render the mass infusible. On completion of the lining the interior of the bricks is preserved against oxidation by fluid cinder added to bind them together, which prevents contact with the flame.

After a fortnight's working on a rotative furnace lined partly with bauxite and partly with plumbago bricks, the brick lining was reduced from 6 in. to less than ½ in., whereas the bauxite lining was still 5 in. thick and perfectly compact. The composition of the bauxite used was 53·62% alumina, 42·26% peroxide or iron, and 4·12% silica ; on exposure to intense heat it was converted into a solid mass of emery of extreme hardness.

The rotary furnace was described by Siemens as consisting of four generators of the usual construction, with reversing valves and gas producers. The iron rotative chamber was about 7½ ft. in dia. and 9 ft. long, resting on four anti-friction rollers, and had a 7-in. thick bauxite lining. The heated gas and air were introduced through a large orifice at one end of the cylindrical chamber.

In working the furnace a charge of, say, 20 cwt. of ore, previously broken up into fragments, not exceeding the size of peas or beans, and mixed with lime or other fluxing material, was put into the furnace when it was fully heated and revolving slowly. After about 40 min., when a bright red heat had been reached, 5–6 cwt. of small coal were added and the rotative velocity was increased to accelerate the mixing of coal and ore. A rapid reaction resulted, the peroxide of iron, being reduced to magnetic oxide, commenced to fuse, and at the same time metallic iron was precipitated by each piece of carbon, while the fluxing materials formed a fluid slag with the siliceous gangue of the ore. By reducing the speed of the rotary action the mass was continually turned over, presenting new surfaces to the heating lining and to the flame within the rotator. When reduction of the iron ore neared completion the rotator was stopped and the fluid cinder tapped off. Finally the speed of rotation was increased and the mass of iron then collected into two or three metallic balls which were taken out and shingled in the usual way. The furnace was again tapped and was then ready to receive another charge of ore.

The time for working one charge rarely exceeded 2 hr., so that if 10 cwt. of metallic iron were obtained per charge, a day's production of puddled iron would be at least 5 tons.

If anthracite or hard coke were used for reducing the ore it was crushed much finer than coal or brown coal, so that each particle of the reducing agent was fully consumed during the period of chemical reaction. If wood were used it was, for the same reason, charged in larger pieces.

NEWS OF MEMBERS

▶ Mr. N. F. ASTBURY, previously with Messrs. Joseph Sankey and Sons, Ltd., is now Director of Research at the G.K.N. Research Laboratories, Manor Works, Ettingshall, Wolverhampton, Staffs.

▶ Mr. G. R. BELL has taken up the position of general manager at the Winchester Machine Tool Company, 294–296, Lillie Road, Fulham, London, S.W.6.

▶ Mr. D. G. BOXALL has resigned his position with A. V. Roe, Canada, Ltd., and has accepted a position as physical metallurgist with the British Columbia Research Council at the University of British Columbia, Vancouver, B.C., Canada.

▶ Mr. HENRY C. BOYNTON has been appointed head of the new metallurgical department at Temple University, Philadelphia, Pa., U.S.A.

▶ Sir JOHN COLVILLE has assumed the title of Lord Clydesmuir ; his correct designation is now the Rt. Hon. Lord Clydesmuir, P.C., G.C.I.E.

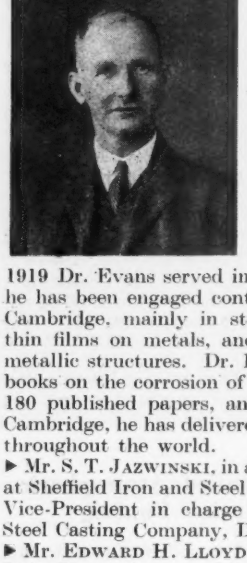
▶ Sr. ISIDRO SANS DARNIS has left the Sociedad Altos Hornos de Vizcaya, on his appointment as Sub-Director of the Instituto del Hierro y del Acero, Villanueva, Madrid.

▶ Mr. L. F. DENARO is now in charge of the recently opened development and research office of the Mond Nickel Co., Ltd., at 25, Claridenstrasse, Zürich, Switzerland.

▶ Mr. R. DIGBY-SMITH has resigned his appointment as general works manager of the Blaenavon Co., Ltd., and has accepted a post in London.

▶ Mr. NORMAN F. DUFTY, who has been senior metallurgist at K. and L. Steelfounders and Engineers, Ltd., has left the country to join the Algoma Steel Corporation, Sault Ste. Marie, Ontario.

▶ DR. ULICK R. EVANS has received the Willis Rodney Whitney Award of the National Association of Corrosion Engineers (of U.S.A.), in recognition of his outstanding contributions to the fundamental knowledge on which the practical control of corrosion is based. Presentation of the award was made at the Association's Annual Banquet, held on 7th April, 1948, at St. Louis, Mo., U.S.A. A native of Wimbledon, London, Dr. Evans was educated at Marlborough College and at King's College, Cambridge. He received the degree of B.A. in 1910, the M.A. in 1914, and Sc.D. in 1932. From 1914 to 1919 Dr. Evans served in H.M. Forces, and since then he has been engaged continuously in scientific work at Cambridge, mainly in studies of corrosion of metals, thin films on metals, and recrystallization changes in metallic structures. Dr. Evans is the author of several books on the corrosion of metals, and of approximately 180 published papers, and in addition to lecturing at Cambridge, he has delivered many lectures by invitation throughout the world.



▶ Mr. S. T. JAZWINSKI, in addition to his present position at Sheffield Iron and Steel Company, has been appointed Vice-President in charge of operations at the Detroit Steel Casting Company, Detroit, Michigan.

▶ Mr. EDWARD H. LLOYD has left the Mond Nickel Co., Ltd., Birmingham, and has joined the staff of Industrial Newspapers, Ltd., as assistant editor of *Sheet Metal Industries*.

▶ Mr. W. D. MARSH has left Murex Welding Processes,

Ltd., Waltham Cross, and is now with the Research Department of Messrs. Hadfields, Ltd., Sheffield.

▶ Mr. M. M. MISRA has left the Enfield Foundry Co., Ltd., and has gone to Messrs. William Asquith's Foundry, Halifax, to further his practical training.

▶ Mr. J. NUTTING has been awarded the degree of Ph.D. at Leeds University for a thesis on the overheating and burning of steel. He has now taken up an appointment with the British Iron and Steel Research Association at the Cavendish Laboratory, Cambridge.

▶ Mr. H. F. PADBURY has succeeded Mr. E. HEMINGWAY JONES as Chairman of the Ebbw Vale Metallurgical Society and as an Honorary Member of Council of The Iron and Steel Institute.

▶ Mr. R. NICHOLSON PARKINS has been appointed lecturer in metallurgy at King's College, Newcastle-upon-Tyne.

▶ Miss D. PILE has resigned her position as secretary and has been appointed treasurer of Sheet Metal Industries Association, Ltd.

▶ Professor A. PORTEVIN, an Honorary Member of The Iron and Steel Institute, has been promoted to the rank of Commandeur of the Legion d'Honneur.

▶ Mr. S. W. RAWSON has recently been elected President of the National Federation of Engineers' Tool Manufacturers.

▶ Dr. I. G. SLATER, formerly scientific adviser, British Admiralty Delegation, Washington, U.S.A., is returning to this country to take up an appointment as Director of Operational Research, Admiralty, London, S.W.1.

▶ Dr. G. V. SLOTTMAN has been appointed technical assistant to the Vice-President of Air Reduction, New York.

▶ Mr. H. SNOW, of Messrs. Samuel Osborne and Co., Ltd., has left the Sheffield works to go to South Africa for the same firm. His new address is P.O. Box 3162, Johannesburg.

▶ Mr. WILLIAM B. TODD has been elected Executive Vice-President and Director of the Continental Foundry and Machine Company, 903, Grant Building, Pittsburgh, Pa., U.S.A.

▶ Mr. A. S. WARD has resigned the position of Managing Director, but continues to hold that of Chairman, of the Park Gate Iron and Steel Co., Ltd. Mr. T. W. EDWARDS and Mr. C. H. T. WILLIAMS become Joint Managing Directors.

▶ Mr. F. S. WILSON has left Messrs. P. R. Jackson and Co., Ltd., Salford, to take up a position as a research metallurgist at David Brown Foundries Co., Ltd., Penistone, Sheffield.

▶ Mr. E. G. WILLOCK, formerly blast-furnace superintendent of the Indian Iron and Steel Co., Ltd., has now returned to England. He has taken a position on the metallurgical staff of Messrs. John Miles and Partners (London), Ltd.

Memoranda

▶ Apex Construction, Ltd., Chemical Engineers, have changed their address to 15, Soho Square, London, W.1.

▶ Wrexham Steel Works, Ltd., which was known as the Brymbo Steel Co., Ltd., before the recent transfer to Guest Keen and Nettlefolds, Ltd., has now changed its name to Brymbo Steel Works, Ltd.

Obituary

The Council regret to record the deaths of:

Mr. JOS. H. HARRISON, of Messrs. Jos. H. Harrison and Son, Consulting Engineers, Middlesbrough, on 6th April, 1948, aged 88.

Lt.-Col. J. H. COLDWELL-HORSFALL, on 17th March, 1948, at Northumberland House, Leamington Spa.

Sr. GREGORIO PRADOS URQUIJO, Central Siderurgica, Bilbao, Spain, on 29th November, 1947.

Mr. GEORGE PHILIP WEST, formerly of Messrs. Colvilles, Ltd., Glasgow, on 18th March, 1948.

CONTRIBUTORS TO THE JOURNAL

J. H. Chesters, D.Sc.Tech.—Assistant Director of Research, The United Steel Companies, Ltd. Having graduated at Sheffield University in 1928 with an honours degree in physics, Dr. Chesters immediately turned his attention to refractories, a subject upon which he is a widely acknowledged authority, and carried out extensive research at Sheffield University (1928–31), where he was awarded the degree of Ph.D., at the Kaiser-Wilhelm-Institut für Silikatforschung, Berlin (1931–32), and at the University of Illinois (1932–34). In 1934 he was appointed in charge of the Refractories Section of the Central Research Department of The United Steel Companies, Ltd., and held this position until 1945, when he became Assistant Director of Research. In that year also he received the degree of D.Sc.Tech. of Sheffield University. At the Annual General Meeting of the Institute held in May 1947 Dr. Chesters was awarded the first Sir Robert Hadfield Medal "in recognition of his work on refractories for use in the iron and steel industries and for his share, as co-author, in preparing Special Report No. 37 (1946), on '*The Influence of Port Design on Open-Hearth Furnace Flames.*'"

J. Mackenzie, B.Sc., Dipl.R.T.C.—Head of the Refractories Section, The United Steel Companies, Ltd., Research and Development Department, Stocksbridge, near Sheffield. Mr. Mackenzie was born in Aberdeen and educated at Queens Park School, Glasgow, and the Royal Technical College, Glasgow, where he graduated in chemistry and metallurgy in 1944. Since then he has been engaged in research on refractory materials with The United Steel Companies, Ltd., and was appointed to his present position in March 1947.

H. L. Diamond, M.Sc.(Eng.), A.M.I.Mech.E.—Head of the Mechanical Section, Plant Engineering Division, British Iron and Steel Research Association. Mr. Diamond graduated with honours at King's College, London, in 1922 and then became a pupil of the late Sir Henry Fowler at Derby Locomotive Works. In 1926 he joined

H. L. Diamond

J. H. Chesters

M. R. Hopkins

J. Pearson

the editorial staff of the Institution of Mechanical Engineers, but continued his interest in locomotives and gained the M.Sc.(Eng.) degree in 1935. During the war Mr. Diamond became Inspector (components) of armoured fighting vehicles at the Ministry of Supply. He took up his present appointment at B.I.S.R.A. in March 1946.

J. Pearson, Ph.D., M.Sc., F.R.I.C.—Head of the Chemistry Section of the Swansea Laboratories of the British Iron and Steel Research Association. Dr. Pearson graduated in 1933 at the University of London with first-class honours in chemistry and obtained his M.Sc. degree in 1934 after a period of research in organic chemistry. In that year he joined the Research Department of Tube Investments, Ltd., to carry out work in connection with the manufacture of steel tubes and allied products. From 1937 to 1946 he was employed in the explosives branch of the Armament Research Department, Ministry of Supply, and obtained his doctorate in 1946 for research work on the polarography of organic compounds. He took up his present appointment in June 1946.

M. R. Hopkins, M.Sc., F.Inst.P.—Head of the Physics Section of the Swansea Laboratories of the British Iron and Steel Research Association. Mr. Hopkins graduated with first-class honours in physics at University College, Swansea, in 1934, and was awarded the College Diploma in mathematical physics in 1936. His M.Sc. degree was awarded for research on the mathematical theory of heat conduction. In 1936 he joined the staff of the Metrology Division of the National Physical Laboratory and in 1942 was seconded on loan from the National Physical Laboratory to Messrs. Taylor, Taylor & Hobson, Ltd., Leicester, to carry out research on the measurement of surface finish. On his return in August 1945 he joined the newly formed Mathematics Division of the National Physical Laboratory. Mr. Hopkins, who has published work on heat conduction and on surface finish, took up his present appointment in October 1946.

I. M. D. Halliday, B.Sc. (Hons.), A.R.T.C.—Engaged upon furnace design at the Research and Development Department of The United Steel Companies, Ltd. Born at Iquique, Chile, Mr. Halliday was educated at Morrison's Academy, Creiff, and at Rothesay Academy, Bute. From 1936 to 1940 he studied applied chemistry and metallurgy at Glasgow University and at the Royal Technical College, Glasgow. He joined The United Steel Companies, Ltd., in 1940, and was for five years a member of the Refractories Section of the Central Research Department. Since 1945 he has been working with Dr. J. H. Chesters on furnace design. Mr. Halliday is a co-author of a number of papers on refractories and furnaces.

IRON AND STEEL ENGINEERS GROUP

Seventh Meeting

The Seventh Meeting of the Iron and Steel Engineers Group will be held at the offices of the Institute, 4, Grosvenor Gardens, London, S.W.1, on Tuesday, 22nd June, 1948, commencing at 10.30 A.M. A buffet luncheon will be served in the Library of the Institute. Details of the papers to be presented and discussed will be found in the April, 1948, issue of the *Journal*.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Tests on New Paint Inhibitors

Extensive recent developments in the ranges of media and inhibitive pigments available for the preparation of priming paints have considerably influenced anti-corrosion researches on iron and steel.

Some interim details of work in this connection by the Protective Coatings Sub-Committee of The Iron and Steel Institute and the British Iron and Steel Research Association have recently been published in a report entitled "*Interim Report on the First Series of Tests on Formulated Priming Paints for Structural Steelwork (RJ28)*," by Joint Technical Panel J/PI—Paints for Structural Steelwork. Copies are available from the British Iron and Steel Research Association.

The work is a natural sequel to the Sub-Committee's previous investigations on the paramount importance of careful preparation of steel surfaces prior to paint application.

A panel has accordingly been set up by the joint Sub-Committee in collaboration with the National Federation of Associated Paint, Colour, and Varnish Manufacturers of the United Kingdom, the Society of British Paint Manufacturers, Ltd., and the Association of Manufacturers of Bituminous Protective Products, Ltd. This joint technical panel is testing 100 formulated priming paints, suitable for brush application, by exposure on steel plates. A standard finishing coat was applied, and the exposure tests have been duplicated in an industrial atmosphere (Derby) and a marine atmosphere (Brixham).

Twelve experimental binding media are under test; these are a linseed-stand-oil/alkali-refined-linseed-oil medium, five alkyd media of various compositions, one 100% phenolic and two modified phenolic media, two coumarone media, and a natural-resin medium.

Twelve different pigments are under investigation, namely, asbestine, barium chromate, basic lead chromate, basic lead sulphate, Burntisland red, chromated white lead, ferrous ammonium phosphate, red lead, white lead, zinc chromate, zinc oxide, and zinc tetrahydroxychromate. Various binary or ternary mixtures of these have been incorporated in the media prepared for tests. Asbestine is not used as a major pigment but as a standard extender throughout and forms 20% of the total pigment content in the case of the ternary mixtures.

Care was taken to ensure that all the paints were prepared under conditions approximating as closely as possible to large-scale production and that they were applied to steel specimens in typical and standardized states of surface preparation. In order to give the maximum practical bias to the results, considerable importance was attached to conducting tests on weathered and wire-brushed steel carrying mill-scale.

The tests will not reach their first stage of completion until later this year, but certain interim observations were made after 6 months. These interim results indicate

that, when considering the effect of this formulation of a priming paint on the protective value of a painting scheme, due regard must be paid to the factor of paint film thickness, *i.e.*, the behaviour of any given painting scheme must be considered in relation to the average performance of other schemes of the same thickness.

Even with skilled application of the paint under good conditions, the specimens concerned showed a variation in paint film thickness between 50 and 120 microns, though 50% of the specimens fell between 60 and 80 microns, and over 40% between 80 and 100 microns. Assessments of the deterioration of the specimens based on blistering, flaking, and rusting show that there is a distinct correlation between the average performance of a group of painting schemes and their average paint film thickness.

Another variable is introduced by the difficulty of reproducing standardized degrees of descaling on the surface of a large number of steel specimens prepared for painting by weathering and wire-brushing. As a result of experience in this test series, the Panel has made certain alterations in the experimental procedure which should reduce these variations and also the variations in paint film thickness mentioned above.

Another interesting interim observation concerns the comparative rates of deterioration of the paints at Brixham and Derby. Although the average paint film thickness at Brixham (52 microns) is slightly greater than that at Derby (47 microns) it appears that up to 6 months the rate of deterioration is more rapid in the marine than in the industrial atmosphere. This observation is confirmed when the merit figure in each case is correlated with paint film thickness.

Staff

Mr. R. H. MYERS has retired from his position as Head of the Steelmaking Division of the British Iron and Steel Research Association, owing to ill-health. He is succeeded by Dr. A. H. LECKIE, formerly Deputy Head of the Division. Both Mr. Myers and Dr. Leckie served with the Technical Department of the British Iron and Steel Federation under the Iron and Steel Industrial Research Council before the formation of B.I.S.R.A. in 1945, so that the Association still maintains a link with the previous co-operative research organization in the iron and steel industry.

AFFILIATED LOCAL SOCIETIES

Ebbw Vale Metallurgical Society

At the Annual General Meeting of the Ebbw Vale Metallurgical Society, on Thursday, 22nd April, 1948, the following officers were elected for the session 1948–1949:

Chairman:

H. F. PADBURY, A.I.M.

Vice-Chairman and Treasurer:

R. C. POWELL, B.Sc.

Honorary Joint Secretaries:

F. W. LEWIS AND E. G. BRACE

INSTITUTION OF METALLURGISTS

Registrar-Secretary

The Council of the Institution of Metallurgists have appointed Arthur D. Merriman, G.C., O.B.E., M.A. (Cantab.), M.Ed. (Dunelm), D.Sc. (Lille), to the full-time post of Registrar-Secretary; he took up his duties in April, 1948. Dr. Merriman's initial training was in physics, mathematics, and chemistry, and after service in the 1914–18 war he had some 20 years' experience in academic fields, including the post of Principal of the County Technical School, Wallsend-on-Tyne (1926–38). For nearly two years before the 1939–45 war he was Administrative Secretary to the Faculty of Architects and Surveyors, but was called to serve the Directorate of Scientific Research, Ministry of Supply, early in that war. He was the senior member of a group of scientists and engineers dealing with bomb-disposal problems, and for his personal courage in emergency situations was awarded the George Cross. From 1941 to 1944 he was Scientific Adviser to the Commander-in-Chief, Middle East, and in 1944 was appointed to a special Intelligence assignment in Russia, followed by similar work in north-west Europe and Germany. He left the service in 1945 with the rank of Colonel, Royal Engineers, and since then has been Principal Scientific Officer (Technical Intelligence) at the Armaments Design Department, Ministry of Supply. He has had considerable experience as a lecturer and writer (he is the author of some 16 books on scientific subjects), and is a Companion of the Institution of Mechanical Engineers and a Fellow of the Corporation of Certified Secretaries.

It will be recalled that hitherto Dr. Harold Moore, C.B.E., the Institution's first President, has served as Registrar. The Council wish to take this opportunity of recording their deep appreciation of the assistance which he has given to the Institution since its foundation, and are pleased to be able to inform Members that he has agreed to continue to make his experience available in a consultative capacity for six months. Dr. Moore, as a Past-President, remains, of course, a Member of Council of the Institution.

Under an agreement with The Iron and Steel Institute and the Institute of Metals, Mr. K. Headlam-Morley, Secretary of the former Institute, has acted also as Secretary of the Institution, while clerical duties have been carried out by the staff of the Institute. It has now been decided, by mutual agreement, to bring this arrangement to an end. Office accommodation will continue to be provided for the Institution at 4, Grosvenor Gardens, London, S.W.1.

The Council of the Institution wish to record their appreciation of the assistance given by the two Institutes and of the services rendered by Mr. Headlam-Morley and the staff.

NEWS OF SCIENCE AND INDUSTRY

American Society for Testing Materials — Annual Meeting

The 1948 Annual Meeting of the American Society for Testing Materials is to be held in Detroit from 21st to 25th June, 1948. During that week there will be some 20 technical sessions and more than 300 meetings of the Society's technical committees. Displays of testing apparatus and laboratory supplies and photographs submitted by members and member firms on photomicrography, radiography, and other related subjects, will be exhibited.

One of the main features of the meeting will be the 1948 Edgar Marburg Lecture, to be delivered by Dr. Paul Aebersold, Chief of the Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn., who is expected to discuss the industrial applications of tracer isotopes. The lecture is to be held on Thursday, 24th June, 1948, at Rackham Memorial Building.

Mr. T. A. Boyd, President of the Society, will give the annual presidential address at the dinner to be held on Wednesday, 23rd June, 1948.

University Professors' Visit to Sheffield

By invitation of The United Steel Companies, Ltd., a number of University Professors of Mechanical Engineering visited the Company's steelworks at Sheffield and Scunthorpe during the four days 12th–15th April, 1948. In addition to seeing modern steelmaking and manipulating processes and plant development, discussions were held on general research problems and on points arising out of observations made during the visit. A discussion on industrial research was opened by Sir Charles Goodeve, O.B.E., F.R.S., Director of the British Iron and Steel Research Association.

British Pig-Iron Production

Production figures for the week ending 10th April, 1948, included an unusually high pig-iron output at the Margam steelworks of the Steel Company of Wales, Ltd.; 5420 tons were produced from a single blast-furnace. This furnace, which was blown in on 8th August, 1946, was designed to produce 700 tons per day or 4900 in a continuous working week, and it has therefore beaten its target by 520 tons in the week, or over five-sevenths of a day's capacity. A description of the blast-furnace, which has a hearth diameter of 21 ft. 6 in., was published on page 289 of the February, 1947, issue of the *Journal*.

Institution of Mining Engineers—Summer Meeting

The Summer Meeting of the Institution of Mining Engineers will be held at Newcastle-upon-Tyne on Wednesday, Thursday, and Friday, 9th, 10th, and 11th June, 1948. The headquarters of the Institution during the meeting will be at Neville Hall, Westgate Road, Newcastle-upon-Tyne.

Netherlands Physical Society

The Netherlands Physical Society is organizing an international conference on the physics of metals, to be held at Amsterdam, from 12th to 18th July, 1948, after the Assembly of the International Union of Pure and Applied Physics. Particulars of the conference may be obtained from Professor C. J. Gorter, Kammerlingh Onnes Lab., Nieuwsteeg, 18, Leylen.

Summer School in Metal Physics

By the courtesy of Professor Sir Lawrence Bragg, O.B.E., F.R.S., a summer school in metal physics will be held from Monday, 23rd August, to Friday, 3rd September, 1948, in the Cavendish Laboratory, Cambridge. The lectures will deal with the application of X-ray methods in the examination of metals, and physical and mechanical properties of metals. A detailed syllabus and form of application for admission may be obtained from G. F. Hickson, M.A., Secretary of the Board of Extra-Mural Studies, Stuart House, Cambridge, to whom the completed application form should be returned **not later than 1st June, 1948.**

Summer School in X-Ray Crystallography

A summer school in X-ray crystallography will be held from 6th to 17th September, 1948, in the Physics Department of the Manchester College of Technology, under the direction of Dr. H. Lipson. The course is designed to meet the needs of those who wish to make use of X-ray diffraction in both industrial and academic research, but who have not had opportunity to acquire the basic training. Further details may be obtained from the Director of Extra-Mural Studies, the University, Manchester, 13.

International Engineering Congress

An International Engineering Congress is to be held in Paris for four days at the beginning of October, 1948. Members who are desirous of attending should reply to the British Engineers' Association, 32, Victoria Street, London, S.W.1.

Summer School in the Physics of Solids

The University of Bristol, in co-operation with the Institute of Physics, announces that a second summer school in physics (experimental and theoretical) will be held in Bristol from 8th to 15th September, 1948. Further details will be published in due course.

DIARY

26th–29th May—INSTITUTE OF VITREOUS ENAMELLERS—Spring Meeting—Bournemouth.

28th May—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—Annual General Meeting—Royal Institution of South Wales, Swansea, 6.30 P.M.

1st–3rd June—International Congress on Analytical Chemistry—Utrecht, Holland. (*General Secretary*: H. A. J. Pieters, 7, Beatrixlaan, Geleen, Holland.)

2nd–4th June—NATIONAL ASSOCIATION OF COLLIERY MANAGERS—International conference on technical aspects of coal-mining—Queen Hotel, Harrogate.

4th–6th June—NATIONAL ASSOCIATION OF DROP FORGERS AND STAMPERS—First Annual Convention—Llandudno.

9th–11th June—INSTITUTION OF MINING ENGINEERS—Summer Meeting—Neville Hall, Westgate Road, Newcastle-upon-Tyne.

10th–11th June—SHEET AND STRIP METAL USERS' TECHNICAL ASSOCIATION—Summer Technical Conference—Birmingham.

21st–25th June—AMERICAN SOCIETY FOR TESTING MATERIALS—1948 Annual Meeting, Detroit, U.S.A.

22nd June—IRON AND STEEL ENGINEERS GROUP—Seventh Meeting—4, Grosvenor Gardens, London, S.W.1, 10.30 A.M.

TRANSLATION SERVICE

(The previous announcement was made in the April, 1948, issue of the *Journal*, page 526.)

TRANSLATIONS AVAILABLE

No. 343 (German). A. POMP and W. PUZICHA: "The Cold-Rolling of High-Tensile Strip Steels and Their Properties." (*Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung*, 1943, vol. 26, No. 2, pp. 13–36).

PAPER ACCEPTED FOR TRANSLATION SINCE THE LAST ANNOUNCEMENT

(French). H. BERSOUX: "Life, Defects, and Scrapping of Rolls—General." (*Revue Universelle des Mines*, 1945, Series 9, vol. 1, Aug.–Sept., pp. 65–71).

CHARGES FOR COPIES OF TRANSLATIONS.—For the above translations a charge will be made of 10*s*. for the first copy and 5*s*. each for each additional copy of the same translation. Requests should be accompanied by a remittance. The above translations are not available on loan from the Joint Library.

TRANSLATIONS PREPARED AT MEMBERS' REQUEST.—Members requiring translations of foreign papers are invited to communicate with the Secretary, who will ascertain whether the translations can be prepared for inclusion in the series.

ABSTRACTS OF CURRENT LITERATURE *and* BOOK NOTICES

IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

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MINERAL RESOURCES

The Princeton Coal Field, British Columbia. E. R. Hughes. (Transactions of the Canadian Institute of Mining and Metallurgy, 1947, vol. 50, pp. 665–676). The past and present history of coal mining in the Princeton area, 182 miles east of Vancouver, is described.—R. A. R.

Noamundi Iron Mine. F. G. Percival. (Tisco Review, 1947, vol. 15, Sept., pp. 232–242). A detailed description of the Noamundi iron ore mine of the Tata Iron and Steel Co., Ltd., is given. The mine is estimated to contain about 600 million tons of ore which is almost entirely hematite.—R. A. R.

Chromite Deposit of Cavalaire (Var). (Génie Civil, 1948, vol. 125, Feb. 1, p. 54).—R. F. F.

Utilization of Ores of the Longwy District. Guinard and Godefroy. (Revue de Métallurgie, 1947, vol. 44, Jan.–Feb., pp. 1–11). The greater part of the iron ores of the Longwy district are siliceous. The geology of the ore deposits and the use and nature of the ores were studied mainly from the economic viewpoint.—R. F. F.

On the Presence of Francolite and the Distribution of Phosphorus in the Iron Ores of Moulaine. Simone Caillère and F. Kraut. (Académie des Sciences, 18 Nov., 1946 : Centre de Documentation Sidérurgique, Supplément à la Circulaire d'Informations Techniques, 1947, vol. 2, Aug. 25, pp. 21–22).—J. C. R.

Zirconium Deposits in North-Western Poland. J. Zwierzycki. (Hutnik, 1947, vol. 14, Mar., pp. 150–152). [In Polish]. Examination of sands from north-western Poland has shown that zirconium and ilmenite are present in useful quantities.—W. J. W.

Chromite Deposits of the Fethiye and Dagardi Regions, Turkey. V. Kovenko. (Maden Tetkik Arama Enstitüsü Mecmuasi (Ankara), 1945, vol. 10, pp. 42–75, pp. 59–75 [in French]: Chemical Abstracts, 1948, vol. 42, Feb. 10, 847).

Iron Mines of Minnesota. Methods and Materials. J. Aubéry. (Revue de l'Industrie Minérale, 1947, Dec., pp. 749–779). The iron mines of Minnesota are surveyed with special reference to methods of exploitation.—R. F. F.

Drill-Hole Correlation as an Aid in Exploration of Magnetite Deposits of the Jersey Highlands, New York and New Jersey. H. E. Hawkes and P. E. Hotz. (United States Department of the Interior, Geological Survey, 1947, Bulletin 955-A).

Chromite Deposits near Red Lodge, Carbon County, Montana. H. L. James. (United States Department of the Interior, Geological Survey, 1946, Bulletin 945-F).

Manganese Deposits of the Republic of Haiti. E. N. Goddard, L. S. Gardner, and W. S. Burbank. (United States Department of the Interior, Geological Survey, 1947, Bulletin 953-B).

Iron Ore Resources of Japan. T. G. Andrews. (General Headquarters, Supreme Commander for the Allied Powers (Tokyo), Natural Resources Section, Report No. 69, 1947 : Chemical Abstracts, 1948, vol. 42, Jan. 20, p. 495). The home islands produced nearly 20 million metric tons of iron ore from 1925 to 1945, which was about 26% of the total consumption. The reserves are small and mostly low grade.

Nickel Deposits in Japan. (British Intelligence Objectives Sub-Committee, 1948, Report No. B.I.O.S./J.A.P./P.R./1430 : H.M. Stationery Office).

Cobalt Resources in Japan. (British Intelligence Objectives Sub-Committee, 1948, Report No. B.I.O.S./J.A.P./P.R./1553 : H.M. Stationery Office).

Chromite Resources of Japan. (British Intelligence Objectives Sub-Committee, 1948, Report No. B.I.O.S./J.A.P./P.R./1595 : H.M. Stationery Office).

Petrology and Structure of the Moa Chromite District, Oriente Province, Cuba. P. W. Guild. (Transactions of the American Geophysical Union, 1947, vol. 28, pp. 218–246 : Chemical Abstracts, 1948, vol. 42, Feb., 847).

Coal Deposits of Semirara Island, Antique Province, P.I. N. N. Lim. (Philippine Geologist, 1947, vol. 2, Dec., pp. 10–17).

ORES—MINING AND TREATMENT

The Mechanization of Iron Ore Mining at the Mines of Richard Thomas & Baldwins Ltd., at Irthlingborough, Northants. W. E. Davies. (Bulletin of the Institution

of Mining and Metallurgy, 1948, Jan., No. 494). The Irthlingborough iron-ore mines are worked on the pillar-and-stall system and production has been increased by the adoption of mechanical loading and haulage. The method of working is explained and the advantages of mechanization are pointed out.—R. E.

The Development and Maintenance of Coal Cutting and Loading Machines. H. Kuhlmann. (Glückauf, 1948, vol. 81–84, Jan. 17, pp. 35–52).

Brazilian Ore Resources and the Volta Redonda Plant. R. Vaill. (Blast Furnace and Steel Plant, 1947, vol. 35, Nov., pp. 1365–1367; Dec., pp. 1488–1489, 1538). Brazilian resources of high-grade iron ores are extremely abundant, ore deposit alone consisting of 500 millon tons of easily mined massive hematite containing up to 70% of iron and remarkably free from impurities. A native iron and steel industry founded upon charcoal has been in existence since 1820 but has left the "hematita compacta," considered to be the world's finest iron ore, untouched. The origins of the Cia Siderurgica Nacional are outlined, and the erection and operation of the modern integrated iron and steel works at Volta Redonda are discussed.—J. R.

Transportation of Iron Ore, Underground Mines Lake Superior District. J. A. Johnson and F. E. Cash. (United States Bureau of Mines, Nov., 1947, Information Circular 7419).

Continuous Ore Transport. R. W. Rausch. (American Institute of Mining and Metallurgical Engineers: Mining and Metallurgy, 1947, vol. 28, Dec., pp. 590–595). Belt conveyor design and application in mining are discussed.—R. A. R.

Concentrating Minette. W. Luyken. (Stahl und Eisen, 1948, vol. 68, Jan. 29, pp. 35–38). Old and recent tests on the concentration of Minette ores from Lorraine and Luxemburg are reviewed and details of their structure and mineralogical composition are given. —R. A. R.

Some Notes on Sintering with Increased Vacuum. S. Jansson and C. Danielsson. (Jernkontorets Annaler, 1948, vol. 132, No. 1, pp. 15–26). [In Swedish]. Iron ore for producing high-phosphorus pig iron for the basic-Bessemer process was sintered in a Greenawalt plant at Domnarfvet using three degrees of vacuum, namely, 2200, 1500, and 1000 kg./sq. m. measured at the fan, while other conditions were kept constant. It was found that: (1) The sintering rate increased with the square root of the vacuum; (2) the relative resistance of the charge to the air passing through it scarcely changed; (3) the power consumption increased directly with the vacuum; and (4) there was practically no change in the quality of the sinter produced.—R. A. R.

The Sintering of Iron Ore with Added Lime. J. Klärding. (Iron and Steel Institute, 1948, Translation Series, No. 336). This is an English translation of a paper which appeared in Archiv für das Eisenhüttenwesen, 1939, vol. 12, May, pp. 525–528 (*see* Journ. I. and S.I., 1939, No. II, p. 59A).—R. A. R.

Beneficiation of Western Manganese Ores. C. H. Schack and H. G. Poole. (United States Bureau of Mines, Sept., 1947, Report of Investigations 4117).

Pilot Mill Concentration of Las Vegas Wash Manganese Ore, Boulder City, Nev. S. R. Zimmerley and C. H. Schack. (United States Bureau of Mines, Sept., 1947, Report of Investigations 4123).

Concentration of Oxide Manganese Ore from the Ophir Hill Mine, Ophir Tooele County, Utah. S. J. Hussey, T. F. Mitchell, and J. A. McAllister. (United States Bureau of Mines, Oct., 1947, Report of Investigations 4130).

Concentration of Carbonate and Oxide Manganese Ores from the Vicinity of Tracy, Central California. B. K. Shibler, W. W. Agey, and K. C. Vincent. (United States Bureau of Mines, Nov., 1947, Report of Investigations 4137).

Beneficiation of Oxide and Carbonate Manganese Ores from the Philipsburg District, Granite County, Mont. R. R. Wells, A. O. Ipsen, and K. C. Vincent. (United States Bureau of Mines, Nov., 1947, Report of Investigations 4138).

Concentration of Oxide Manganese Ores from the Vicinity of Long Valley, Coconino County, Ariz. C. H. Schack, H. G. Poole, and A. O. Ipsen. (United States Bureau of Mines, Nov., 1947, Report of Investigations 4140).

Concentration of Manganese Ore from Southeastern Juab County, Utah. B. K. Shibler and R. Havens. (United States Bureau of Mines, Nov., 1947, Report of Investigations 4141).

Concentration of Oxide Manganese Ores from the Artillery Peak Deposit, Mohave County, Ariz. R. Havens, G. M. Potter, and S. J. Hussey. (United States Bureau of Mines, Nov., 1947, Report of Investigations 4148).

Concentration of Oxide Manganese Ore from Sheep Mountain Property, Durkee District, Oreg. R. R. Wells and W. W. Agey. (United States Bureau of Mines, Nov., 1947, Report of Investigations 4149).

FUEL—PREPARATION, PROPERTIES, AND USES

Steam Plant Heat Balances. C. F. Wade. (Power and Works Engineering, 1947, vol. 42, Feb., p. 38; Mar., p. 87; May, pp. 138–139; July, pp. 209–210; 1948, vol. 43, Jan., pp. 20–22; Mar., pp. 90–91). Methods of obtaining steam-plant operating data and applying them to calculate heat balances are described.—R. A. R.

Problems of Heat Transfer in Boilers. (Engineering and Boiler House Review, 1948, vol. 63, Jan., pp. 4–7; Feb., pp. 49–52, 60). Methods of determining the heat transfer in boilers are explained with special reference to the radiation effect of luminous and non-luminous flames, and oil-fired installations.—R. A. R.

Modern Practice in Iron and Steel Manufacture and Fuel Economy. A. G. Lefebvre. (Revue Technique Luxembourgeoise, 1948, vol. 40, Jan.–Mar., pp. 25–32). Methods of saving fuel in operating blast-furnaces and the efficient utilization of blast-furnace gas are surveyed. The importance of a central control to reduce the waste of fuel in all parts of steelworks is emphasized.—R. F. F.

Some Aspects of the Fuel Industry. Use of Tar Substitutes in the Manufacture of Agglomerates. C. Berthelot. (Chimie et Industrie, Technologie, 1944, vol. 52, pp. 143–151).

Experiments in Coking Mixtures of Coal, Blast-Furnace Flue Dust and Iron Ore. M. Clyzewski and O. Goszyk. (Hutnik, 1947, vol. 14, Mar., pp. 132–139). [In Polish]. Experiments carried out by the authors using coking coal and gas coal for coking with addition of blast-furnace flue dust and iron ore have shown the inferiority of the products. The inferiority of the coke decreases with increasing proportions of coking coal.—W. J. W.

The Modern Coke Plant. T. J. Ess. (Iron and Steel Engineer, 1948, vol. 25, Jan., pp. C3–C37). Comprehensive reviews, descriptions, and statistics are given of modern coke-oven (including beehive-oven-) and by-product-plant developments, layout, design, equipment, and operation. The locations and estimated annual capacities of integrated coke-oven plants in the United States are listed in an appendix.—J. R.

Coking Operations at Norwood Works. (Iron and Coal Trades Review, 1948, vol. 156, Feb. 27, pp. 423–426).

Constructional and operational details are given of the new coking plant recently put into commission at the Norwood Coke Works, Dunston-on-Tyne. The installation consists of two batteries, each of 33 Simon-Carves under-jet regenerative ovens, situated one on either side of a central coal service bunker. The ovens are each 42 ft. 3 ½ in. long by 12 ft. 6 in. high and, with a mean width of 20½ in., are probably the widest silica-brick ovens in the country. An interesting feature is the incorporation of an infra-red-beam safety and alignment device for control of the pusher motor.—J. R.

Method for the Determination of Pressure Due to the Dilatation of Coal during Coking. N. R. Kouchairevitch. (Zavodskaya Laboratoriya, 1947, vol. 13, Mar., pp. 325–328: [Abstract]. Chimie et Industrie, 1948, vol. 59, Jan, p. 45). Results obtained in a laboratory furnace show that the pressure varies, with the type of coal tested, between 0·03 and 0·3 kg./sq. cm.—R. F. F.

Gas Combustion Systems and Burners. H. Schramm. (Industrial Gas Times, 1947, vol. 10, May, pp. 254–262). Atmospheric, high-pressure and low-pressure combustion systems are discussed, and burners for each type are described.—R. A. R.

The Use of Oxygen for Metallurgical Heating in the Iron and Steel Industry. M. W. Thring. (Institution of Chemical Engineers and the Physical Society, Joint Conference on Developments in the Industrial Production and Use of Gaseous Oxygen, Feb., 1948, Advance Copy, pp. 3–8). It is shown that if preheater efficiency could be maintained constant at all temperatures, oxygen enrichment (nitrogen elimination) would have no theoretical advantage over preheat, but that practical limitations of preheater design give oxygen an actual advantage which increases steadily as the heating temperature rises above 1400° C. When applying this argument to the heating processes in the steel industry practical considerations increase further the value of oxygen enrichment. Thus, for open-hearth steelmaking preheat is already used to its limit, but oxygen gives a more rapid combustion which enables the fuel consumption rate in a given furnace to be increased and so shortens the process time. For Bessemer steelmaking an oxygen-enriched blast enables the amount of scrap melted to be materially increased and also improves the metallurgy. For blast-furnaces the use of oxygen is most attractive with processes which require an unusual amount of high-grade heat (ferrosilicon and ferromanganese), but it is likely also to save fuel and increase output with ordinary iron-making. This leads to the conclusion that high-capacity oxygen plants installed in steelworks are likely to be a very important development in the steel industry and lead to fuel saving even when the power used to make the oxygen is assessed, in the way recommended in this paper, as part of the fuel required for the process.—R. A. R.

Combustion with Oxygen and Oxygen-Enriched Air. Part I—Thermodynamic Data and Their Implications for High-Temperature Heating Processes. H. R. Fehling. (Institute of Fuel and Institute of Petroleum, 1948, Mar. 12, Advance Copy). A study is made of the fundamental aspects of combustion with oxygen and the influence of the fuel on the problem. The paper is in five sections, viz.: (1) Basic volumetric and thermal data; (2) composition of combustion gas and dissociation at high temperatures; (3) the It-diagram and the maximum combustion temperature; (4) practical objectives of oxygen enrichment; and (5) implications of the thermodynamic data on high-temperature heating processes.—R. A. R.

TEMPERATURE MEASUREMENT AND CONTROL

The Embrittlement of Chromel and Alumel Thermocouple Wires. W. I. Pumphrey. (Journal of The Iron and Steel Institute, 1947, vol. 157, Dec., pp. 513–514).

Surface-Temperature Measurement. M. Diana Hedgcock and R. Mayorcas. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., pp. 236–247).

High Temperature Pyrometry. N. R. Holbrook. (Journal of the Junior Institution of Engineers, 1947, vol. 58, Dec., pp. 65–72). Short descriptions are given of the common types of optical pyrometers.—C. O.

REFRACTORY MATERIALS

Refractories and Furnace Design. A. L. Roberts. (Industrial Gas Times, 1947, vol. 10, May, pp. 236–238). The characteristics of different refractories and the manner in which they influence furnace design are discussed.—R. A. R.

Observations on the Shelling of Checker-Brick. E. C. Petrie and D. P. Brown. (Journal of the American Ceramic Society, 1948, vol. 31, Jan. 1, pp. 14–20). An investigation of the causes of the spalling and bloating of checkerbrick refractories is reported. An excessive alkali content was probably responsible. The probable source of the alkalis is discussed.—R. A. R.

Modified Differential Thermal Analysis Apparatus. P. G. Herold and T. J. Planje. (Journal of the American Ceramic Society, 1948, vol. 31, Jan. 1, pp. 20–22). An apparatus for making differential thermal analysis to identify clay minerals by studying the exothermic and endothermic reactions on heating to 1000° C. is described.—R. A. R.

Factors Causing Porosity in Dina Bricks. Y. S. Kainarsky. (Ogneupory, 1947, vol. 12, No. 1, pp. 14–26: [Abstract]. Chimie et Industrie, 1948, vol. 59, Jan., p. 60). Amongst suggestions for the prevention of porosity in Dina bricks, the use of fine-grain materials and the addition of lime and iron ($FeO/CaO = 4:1$), in the case of open-hearth linings, are included.—R. F. F.

Operating with a Basic Main Roof. A. K. Moore. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 86–88). Operating experiences with a series of basic main roofs on a 180-ton open-hearth furnace over a period of three years are discussed and tabulated. The net effect has been that production from this furnace has increased by 14·1%, at an additional cost of 80.028 per ton. The fourth roof of the series is still in good conditions after 370 heats.—J. R.

Carbon Hearths for Blast Furnaces. C. J. Fleisch. (Eastern States Blast Furnace and Coke Oven Association and Chicago District Blast Furnace and Coke Association: Iron Age, 1947, vol. 160, Dec. 18, pp. 73–76). **Carbon Hearth Installations at Homestead.** C. J. Fleisch. (Iron and Steel Engineer, 1947, vol. 24, Nov., pp. 93–96). **Design of Carbon Hearths and the Results Obtained at the Carrie Furnace.** C. J. Fleisch. (Blast Furnace and Steel Plant, 1947, vol. 35, Nov., pp. 1359–1360). Details are given of the construction and operation of three blast-furnace hearths, partly constructed of carbon, at the Homestead plant of the Carnegie-Illinois Steel Corporation.—C. O.

Carbon Mold Plugs in Alloy Steel Production. H. F. Walther. (Iron Age, 1947, vol. 160, Nov. 27, pp. 70–73). A description is given of the carbon plugs used by the Timken Roller Bearing Co., in the bottom of moulds for 4000–6100-lb. alloy-steel ingots. These plugs are 4½ in. deep with top and bottom diameters of 5⅞ and 5 $\frac{1}{16}$ in., respectively. They last longer than ceramic plugs, are more accurately made, and are more effective in preventing leaks.—R. A. R.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Iron and Power. W. M. Bonham. (Canadian Mining Journal, 1948, vol. 69, Jan., pp. 55–59). The conditions for the economic production of pig iron in the electric furnace are surveyed, and it is shown that these conditions are satisfied in the St. Lawrence region where ample electric power is available with abundant additional sources of power for future exploitation. High-grade iron ore is also available from the Labrador-Ungava deposits now being developed. A description of the Tysland-Hole electric furnace is given.—R. A. R.

The Electric Blast Furnace. J. V. Lopez. (Anales de Mecanica y Electricidad, 1947, vol. 24, Jan.–Feb., pp. 17–24; Mar.–Apr., pp. 65–73: Electrical Engineering Abstracts, 1948, vol. 51, Jan., p. 21). The author sets out the advantages of the electric blast-furnace for operation in Spain, considering national statistics of steel output and availability of coal. The main characteristics are given, as deduced from operating experiences during the last decade, with particulars of installations and transformers. Production and power consumption figures are given, indicating localities in which the furnace could be usefully exploited.

Two 1500-Ton Blast Furnaces Now Under Construction at South Works, by Carnegie-Illinois Steel Corporation. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 94–98). **Carnegie-Illinois Builds Two New 1500-Ton Blast Furnaces.** (Iron and Steel Engineer, 1947, vol. 24, Dec., pp. 100–105). A description is given of two new blast-furnaces and their ancillary equipment, nearing completion at the South Works of the Carnegie-Illinois Steel Corporation, which are to produce 1500 tons/day. The new furnaces were designed as identical units, and the 28-ft. hearths are bottomed with two courses of 22½ in. × 30-in. carbon blocks of 15 ft. maximum length, laid on the 22½-in. dimension; the hearth walls are lined with an inner course of 15-in. thick carbon blocks and an outer course of the same material, 11¾ in. thick.—J. R.

Blast-Furnace Stove Practice and Design. J. Dale. (Iron and Coal Trades Review, 1948, vol. 156, Mar. 5, pp. 489–491). In a discussion of hot-blast-stove design and practice, with special reference to air and gas distribution, it is suggested that more efficient heat exchange and less deterioration of stove refractories result when the combustion-chamber area is large in proportion to the heating surface and the gas flow; operating and constructional data regarding stove installations at four different blast-furnace plants are quoted in support of this opinion. It is also considered that better air distribution is achieved with the use of double-entry cold-blast inlets on each stove.—J. R.

The Production of Pig Iron from Lean Burdens. G. Bulle. (Iron and Steel Institute, 1948, Translation Series, No. 337). This is an English translation of a paper which appeared in Stahl und Eisen, 1947, vol. 66–67, Feb. 27, pp. 69–78 (*see* Journ. I. and S.I., 1947, vol. 156, July, p. 436).—R. A. R.

Lean Ores—Why Not a Departure from Tradition? (Iron and Steel, 1948, vol. 21, Feb., pp. 55–56). It is suggested that low-grade iron ores should be smelted in their raw state, in smaller and faster blast-furnaces, with complete combustion of the coke and full use of the sensible heat of the gases. Less fuel would be required per ton of metal, the gaseous products would be valueless and demand no utilization, and a type of iron would be produced of special use for steelmaking. J. P. S.

Hot and Cold Blast Mixing Device Gives to Blast a Uniform Temperature. H. E. McDonnell. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 91–93). A simple venturi arrangement for the mixing of hot and cold blast before delivery to the blast-furnace is described and illustrated. The device is installed in the hot-blast main, between the stoves and the furnace, and stringent full-scale tests have shown that a very high degree of mixing is obtained. One such installation has been in continuous use since the end of 1941 without operational or maintenance costs.—J. R.

Blast Furnace Becomes Heat Economy Conscious. O. R. Rice. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 54–56). Carbon-hearth installations and hot-blast-stove operation are discussed with reference to heat economy in the blast-furnace, and developments in high-top-pressure operation and the use of oxygen-enriched blast are mentioned.—J. R.

Sulphur in Coke. J. Šárek. (Hutnické Listy, 1948, vol. 3, No. 1, pp. 9–11) [In Czech]. A study of the literature on the operation of charcoal blast-furnaces leads the authors to the conclusion that acid smelting with a low-sulphur coke could be successfully employed in some larger blast-furnaces.—R. A. R.

High Top Pressure Operation. J. Revie. (Iron and Steel, 1948, vol. 21, Feb., pp. 45–47). A review is given which links up four American papers on the origin, theory, and full-scale operation of high top pressure in blast-furnaces.—R. A. R.

TREATMENT AND USE OF SLAGS

Experience in the Production of Bricks from Blast-Furnace Slag. P. Hüttemann. (Stahl und Eisen, 1948, vol. 68, Feb. 26, pp. 85–90). An illustrated description is given of the German method of making building bricks using granulated and very finely ground blast-furnace slag. The properties of the bricks are discussed. —R. A. R.

Basic-Bessemer Slag. W. Slnuk. (Hutnik, 1947, vol. 14, Feb., pp. 76–82). [In Polish]. In the ternary system CaO–P_2O_5–SiO_2, the author deals with the field bounded by the CaO corner and a line joining $3CaO.P_2O_5$ to $2CaO.SiO_2$, as well as the appropriate binary systems, in considering the citric-acid solubility of basic-Bessemer slags. He draws conclusions about the effect of slag, grain-size, structure, and the influence of SiO_2, on the solubility of P_2O_5.—W. J. W.

Alpine Blast-Furnace Slag. F. Schwarz. (Berg- und Hüttenmännische Monatshefte der Montanistischen Hochschule in Leoben, 1947, vol. 92, Oct.–Nov., pp. 185–190). Details are given of the applications of the slag produced in Austrian blast-furnaces. These include building materials, fertilizers, and raw materials for glass manufacture.

DIRECT PROCESSES

Direct Methods for the Production of Iron. E. Mazanek. (Hutnik, 1947, vol. 14, May, pp. 240–245). Methods of producing sponge iron direct from iron ore are discussed. —W. J. W.

Iron Production by Direct Reduction of Ore in the Electric Furnace. J. V. Lopez. (Anales de Mecanica y Electricidad, 1947, vol. 24, July–Aug., pp. 187–194: Electrical Engineering Abstracts, 1948, vol. 51, Jan. p. 21). Advantages of the direct reduction process in the electric furnace include smaller capital outlay, greater flexibility, closer control and temperatures in the arc zone $> 2000°$ C. thus providing conditions of intense desulphurization, unobtainable in the old type of blast-furnace, and permitting the utilization of pyrites at present discarded. Production figures are given for a number of modern plants producing different classes of iron based on different ores.

Direct Reduction of Iron Ores. G. Grenier. (Echo des Mines, 1946, July, pp. 102–103 ; Aug., pp. 119–120). Various processes for the direct reduction of iron ores are reviewed under the headings of reduction above the melting point and reduction below the melting point.—R. F. F.

Sponge Iron. M. Mathy and P. Mathy. (Mémoires de l'Association des Ingenieurs Sortis de l'Ecole de Liége, 1943, No. 3, pp. 107–115). The processes of manufacture of sponge iron are reviewed and the use of water gas is studied theoretically. Experimental data are given. The properties of the products of reduction are examined. The uses of water-gas for the industrial reduction of iron ores are briefly discussed from the economic point of view.—R. F. F.

PRODUCTION OF STEEL

Polish Iron and Steel. F. Wirth. (Iron and Steel, 1948, vol. 21, Feb., p. 44). Incorporation of the Western Territories into the Polish state has opened up wider perspectives for the Polish iron and steel industry. Difficulties due to war damage of plant and transport facilities remain acute, but pig-iron production, though still low, has risen from 1200 tons in May to 4300 tons in August, 1947.—J. R.

Ferrous Metallurgy in the Recovered Territories of Poland. I. Borejdo. (Hutnik, 1946, vol. 13, Dec., pp. 597–603). [In Polish]. The production of pig iron, steel, cast iron, and other products, together with figures of the employed manpower for the years 1911–1931 are given.—W. J. W.

Instrumentation in Open-Hearth Practice. J. Talfryn Davies. (Swansea and District Metallurgical Society : Iron and Steel Institute, 1948, Special Report No. 39, pp. 28–36). The opinion is expressed that there is room for considerable advantageous instrumentation in the iron and steel industry, particularly in connexion with open-hearth furnaces, but that agreement is lacking in the South Wales district regarding the degree of instrumentation required. The paper draws the open-hearth operator's attention to instrumentation with the object of making him " instrument-minded."

Kinetics of Carbon Elimination from the Steel Bath. L. A. Shvartsman, A. M. Samarin, and M. I. Temkin. (Journal of Physical Chemistry, U.S.S.R., 1947, vol. 21, Sept., pp. 1027–1032). The experiments described were carried out in the absence of slags and with vigorous stirring of the molten metal. It was found that the rate of elimination is determined by the rate of carbon diffusion into the surface of the melt.

Accelerating Carbon Elimination of the Open Hearth Bath. J. N. Hornak. (Iron and Steel Engineer, 1948, vol. 25, Jan., pp. 39–45). In full-scale trials of the injection of pure oxygen, pure nitrogen, and various oxygen/nitrogen mixtures into the open-hearth bath it was found that the agitation of the bath by even an inert gas resulted in an increase in the rate of carbon elimination. Comprehensive test data are presented and show that the gaseous agitation of the bath gave increased production rates without adversely affecting the steel quality. Problems still to be solved are (1) the detrimental effect on the furnace refractories of the splashing of metal and slag during the blowing period and (2) the introduction of the gas into the bath without interference with the charging of adjacent furnaces.—J. R.

The Behaviour of Sulphur in the Gas and the Sulphur Balance in the Basic Open-Hearth Furnace. F. Eisenstecken and E. H. Schultz. (Iron and Steel Institute, 1948, Translation Series, No. 340). This is an English translation of a paper which appeared in Stahl und Eisen, 1932, vol. 52, July 14, pp. 677–686 (*see* Journ. I. and S.I., 1932, No. II. p. 525).—R. A. R.

Open Hearth Developments for 1947. W. C. Kitto. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 57–60). In a review of open-hearth-furnace developments during 1947, the following are among the items briefly discussed : (1) The use of oxygen, (2) superduty silica brick, (3) the all-basic furnace, (4) the use of multiple burners, (5) the sulphur content of available fuels, and (6) the preparation of scrap.—J. R.

Recent Problems and Developments in Steel Making Controls. H. J. Forsyth. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 70–75). The use of control methods during various stages of steelmaking processes has become of increased importance in view of rising production costs and the demand for high-quality products. Some of the methods adopted are discussed.—J. R.

Oxygen in the Steel Industry—Past, Present and Future. G. V. Slottman. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 64–69). The use of oxygen in the steel industry is reviewed and discussed, and it is considered probable that the application will play an increasingly active part in future steelplant operations. Many practical problems are still to be overcome, however, before the development can be considered as an indispensable adjunct to steelmaking practice.—J. R.

Oxygen Activities during 1947. J. H. Zimmerman. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 83–85). Recent developments in the use of oxygen in steelmaking furnaces and for powder-scarfing ingots and billets are discussed. In the latter process a fluxing powder is fed into the oxygen stream.—R. A. R.

Oxygen and the Combustion Process. W. A. Mueller. (Ohio State University, Engineering Experiment Station News, 1947, vol. 19, Dec., pp. 21–24). The use of nearly pure oxygen for the oxidation of carbon in steel furnaces is discussed.

Liquid-Fuel Firing, with Special Reference to Open-Hearth Furnaces. F. A. Gray. (Sheffield Society of Engineers and Metallurgists : Iron and Steel Institute, 1948, Special Report No. 39, pp. 60–80). The properties of the available liquid fuels are discussed ; in particular oil fuels are considered with regard to their use in the open-hearth furnace. Liquid fuels are compared with other open-hearth fuels in relation to flame-radiating power, furnace efficiency, steel output and quality, and furnace design. Equipment for the oil-firing of open-hearth furnaces and the modifications required to the design of gas-fired furnaces, are described and illustrated.

Casting Pit Practice and Ingot Defects. R. N. Duncan. (West of Scotland Iron and Steel Institute, Mar., 1948, Preprint). The manner in which the incidence of ingot defects is affected by ladle design, ingot-mould design, teeming practice, and ingot stripping is discussed from the practical point of view, and some apparent contradictions are explained.—R. A. R.

Developments in the Electric Furnace Industry during 1947. W. J. Reagan. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 61–63). Production from American electric furnaces during 1947 totalled about 3½ million tons, a relatively low figure representing only about 70% of the total capacity. Among the developments discussed are the use of oxygen, the control of power, and the determination of hydrogen contents during the progress of the heat.—J. R.

Power and Power Factor in Arc Furnace Operation. E. H. Browning. (Iron and Steel Engineer, 1948, vol. 25, Jan., pp. 79–86). Electric-arc furnace operation and equipment are discussed with special reference to the power factor. Formulæ for the determination of the electrical efficiency of the furnace are presented and methods for improvement are suggested.—J. R.

The Importance of Preventing Rejections in Relation to the Quality and Economics of Special-Steel Production. O. Pattermann. (Berg- und Hüttenmännische Monatshefte der Montanistischen Hochschule in Leoben, 1947, vol. 92, Oct.–Nov., pp. 178–182).

Constitutional Diagrams for Basic Steel Slags. H. Pettersson. (Jernkontorets Annaler, 1948, vol. 132, No. 2, pp. 42–56). [In Swedish]. The literature on binary and ternary basic-steel slag systems is reviewed and many of the latest constitutional diagrams are reproduced. There are 51 references.—R. A. R.

Existence of Compounds in Fused Slags. L. Losana. (Atti delle Reale Accademie delle Scienze di Torino, 1942–43, vol. 78, pp. 194–202 : British Abstracts, 1948, Jan., Section B1, p. 85). The viscosity of $FeO–SiO_2$ slags at 1330–1520° C. is a minimum at $2FeO . SiO_2$; above approximately 1650° C. the minimum disappears, indicating considerable or complete dissociation. Dissociation appears to increase much more rapidly with temperature than is calculated from the formula of Schenck (Physikalische Chemie der Eisenhüttenprocesse, 1936). The viscosity of $MnO–SiO_2$ slags at 1410–1720° C is a minimum at $2MnO . SiO_2$, which appears to be much less dissociated than the iron compound.

Slag Control and Determination of Optimum Slag Composition in Basic Open-Hearth Practice. A. J. Kesterton. (Cleveland Institution of Engineers : Iron and Steel Institute, 1948, Special Report No. 39, pp. 38–49). The determination in advance of the optimum chemical composition of the tapping slag, as a target for the operation of a slag-control technique, is discussed in relation to the manufacture of rimming steel. The dissolved-oxygen requirement in the steel at tapping for good rimming action, and the relationship between dissolved oxygen and slag composition are considered. It is deduced that at a given carbon concentration the vigour of the rimming action is controlled by the oxygen dissolved in the steel, which in turn is controlled by the slag FeO, provided that the basicity is constant. It is shown how, using Schenck's theories, the effect of the slag composition on the removal of sulphur and phosphorus to below the specification limits can be calculated for a set of steelmaking conditions similar to those prevailing on the North-East Coast of England. The optimum tapping-slag analysis for good rimming action, together with removal of sulphur and phosphorus, can then be deduced. The current methods by means of which tapping-slag compositions are controlled in actual steelmaking practice are outlined and, finally, suggestions are put forward concerning the best method of extraction from plant-operating records of some of the data required for the calculation involved in determining optimum slag composition.

Electric Ingot Method for Continuous Casting Alloys. L. E. Browne. (Steel, 1948, vol. 122, Jan. 19, pp. 74–78). The Kellog process for the production of cast billets of alloy steels, is described. Cold-rolled strip is continuously formed into a tube, and lowered vertically into the mould, which is heated by an arc discharge between the tube and molten metal, the tube serving as a consumable electrode.

Alloying materials are fed at controlled rates from hoppers through the tube into the bath. The mould (which is water-cooled) is continuously lowered as the volume of metal increases. Solidification begins at the bottom side walls, and a liquid bath is thus maintained below the slag layer in the centre of the billet. Operating temperatures are around 3500° F., and the melting rate is 7½ lb./min.—M. A. V.

Alloys Made by Electric Ingot Process Have Improved Properties. H. R. Clauser. (Materials and Methods, 1948, vol. 27, Jan., pp. 57–61). The Kellog process of continuous casting is described (*see* preceding abstract). Besides describing the process the present author gives the properties of some heat-resisting steels made by it.—R. A. R.

Efficiency of Fireclay Hot Tops in Steel Ingot Casting. J. W. Mueller. (Ohio State University, Engineering Experiment Station News, 1947, vol. 19, Dec., pp. 47–48). In an endeavour to reduce crop ends the author has studied the use of different fireclay hot-top materials.

FOUNDRY PRACTICE

Problems in a Quantity Production Foundry. J. Hird. (Institute of British Foundrymen : Foundry Trade Journal, 1948, vol. 84, Mar. 11, pp. 243–250). Problems in the organization of processes in quantity-production foundries are outlined with examples of how some of them have been dealt with at the foundry with which the author is associated.—R. A. R.

Present Problems in the Iron Foundries. A. Ohman. (Teknisk Tidskrift, 1948, vol. 78, Feb. 21, pp. 97–102). [In Swedish]. Problems in Swedish iron foundries are discussed with special reference to : (*a*) Attracting apprentices ; (*b*) mechanization of sand preparation, moulding, and core-making ; (*c*) use of permanent moulds. High-frequency furnaces have been introduced at 10 to 12 Swedish foundries to replace cupolas and several more works are installing them.—R. A. R.

Planning Production in the Foundry. E. Karlsson. (Gjuteriet, 1948, vol. 38, Jan., pp. 1–12). [In Swedish]. After defining production planning the author discusses the factors on which such planning is based. The mechanism for good planning is described and specimens of route cards, job cards and inspection and cost sheets are reproduced.—R. A. R.

Mechanizing the Foundry. C. B. Dick. (American Foundryman, 1947, vol. 12, Dec., pp. 22–31). The advantages which mechanization in the foundry brings to workers and management are explained, and a detailed description is given of the recently completed mechanization at a foundry of the Westinghouse Electric Corporation.—R. A. R.

The Experimental Foundry at the Bureau of Mines. J. E. Rehder. (Canadian Metals, 1947, vol. 10, Nov., pp. 14–16). The experimental foundry of the Physical Metallurgy Research Laboratories of the Bureau of Mines, Ottawa, is described.—R. A. R.

Metallurgy in the Foundry. J. G. Dick. (American Foundryman, 1948, vol. 13, Jan., pp. 60–61).

The Induction-Heated Cupola. (Iron Age, 1948, vol. 161, Feb. 5, pp. 76–78). A description is given of a combined coke and induction-heated cupola for making high-quality iron. A laboratory model 8 in. in inside dia. has been made and used, and a larger one for melting 4 tons/hr. is described ; both were designed by E. Piwowarsky. The lower part of the cupola, well below the tuyere level, is induction-heated, the object being to provide a method of superheating the metal 200° to 400° F. with an energy consumption of only 60–120 kWh./ton. The metallurgical advantages of this melting equipment are outlined.—R. A. R.

Electro-Alloys Foundry Equipped with Latest Type of Facilities. (Blast Furnace and Steel Plant, 1947, vol. 35, Nov., pp. 1361–1364). A description is given of a new $3,000,000 foundry for the production of high-alloy heat- and corrosion-resisting castings at the Elyria works of the Electro-Alloys Division of the American Brake Shoe Co. The equipment includes three electric-induction and three electric-arc melting furnaces, ranging from 200-lb. to 10,000-lb. capacity, and the entire installation has been designed and built

to take advantage of research, engineering, and quality-control methods.—J. R.

Anthracite as Cupola Fuel. C. C. Wright. (Fifth Annual Anthracite Conference : American Foundryman, 1947, vol. 12, Nov., pp. 40–47 ; Dec., pp. 34–37). The five criteria upon which the performance of a cupola can be judged—melting rate, metal temperature, metal quality, fuel efficiency, and quantity tapped—are discussed in turn, to show that interpretations of data from cupola tests may differ widely, depending upon individual viewpoints. The results of experiments with a 36-in. cupola on methods of building the bed, blast rates, bed heights, fuel-bed resistance, and melting performance, using anthracite as fuel, are presented.—R. A. R.

Cast-Iron Crucibles. M. Bardot. (Iron and Steel, 1948, vol. 21, Jan., pp. 23–26 ; Feb., pp. 49–51). A summary is made of the available knowledge regarding the corrosion or solution of cast-iron crucibles by molten aluminium.—J. R.

Mold Strength. H. W. Dietert, H. H. Fairfield, and E. Hasty. (Foundry, 1947, vol. 75, Dec., pp. 94–95). A small instrument for measuring the strength of moulds in terms of the hardness of the mould surface is described and relationships between green, dry, and hot strengths are discussed.—R. A. R.

A Contribution to Investigations into the Life of Ingot Moulds. R. Stumper. (Société Française de Métallurgie : Revue de Métallurgie, 1947, vol. 44, July–Aug., pp. 228–233 : Iron and Coal Trades Review, 1948, vol. 156, Feb. 13, pp. 319–323). The microstructure of cast iron ingot moulds made with and without additions of a synthetic iron high in combined carbon (0·79%), silicon (2·55%), and manganese (0·78%), and the life of such moulds are considered. The synthetic metal, which was prepared in an arc furnace, was superheated, contained oxide, and was rich in gases ; these factors promoted the formation of pearlite in the mixed iron, and were detrimental to the life of the moulds.—R. A. R.

Steel Turbine Castings Production Problems. J. A. Wettergreen. (American Foundryman, 1947, vol. 12, Dec., pp. 51–54). Difficulties in the feeding of large steel castings for turbines, with special reference to the use of Williams risers, are explained and the cleaning of these castings is described.—R. A. R.

Unusual Shakeout Arrangement Speeds Sand Conditioning. (Iron Age, 1948, vol. 161, Feb. 5, p. 75). A mechanical shake-out unit called a "Screenerator" is described. The shake-out table has 2 × 4-in. openings and below it is a ½-in. mesh screen. The machine can deal with up to 1000 lb. of sand per min.—R. A. R.

The Development of Foundry Sand Control. G. L. Harbach. (Institute of British Foundrymen : Foundry Trade Journal, 1948, vol. 84, Feb. 26, pp. 195–199 ; Mar. 4, pp. 223–229). At a mechanized foundry it was found that a local sand which had given good results in hand-rammed green-sand moulds produced inferior castings in power-rammed moulds owing to the close ramming. After a detailed study of the properties of various sands and of methods and tests for the determination of their physical characteristics, a satisfactory mix was evolved. Sand control is considered essential, and details are given of a particular control method in operation.—J. R.

Impurities in Steelfoundry Knock-Out Sand. H. E. Crivan. (Iron and Coal Trades Review, 1948, vol. 156, Jan. 16, pp. 109–117). A list was made of 17 kinds of impurities found in the knock-out sand of a steel foundry, and small cores were prepared with these impurities deliberately included so as to appear flush with the surface. Their effect on the steel castings was noted. Coal and slag lumps caused the greatest trouble. Samples of used sand were quantitatively examined for foreign matter and the results are evaluated and discussed. The dust problem was studied ; up to 4% of water could be added to the knock-out sand without materially altering the grading.—R. A. R.

Synthetic Moulding Sand. J. G. P. Bruschke. (Metalen, 1948, vol. 2, Feb., pp. 120–122). [In Dutch.] The advantages of using synthetic moulding sand are discussed and the preparation and properties of a sand used at a Dutch foundry are described.—R. A. R.

Moulding Boxes. J. B. Morton. (Institute of British Foundrymen : Foundry Trade Journal, 1948, vol. 84, Jan. 29, pp. 97–102). The design and manufacture of moulding boxes are discussed, and a description is given of the production of large cast-iron boxes by the building up of standardized sections.—J. R.

Notes on Pattern Construction. R. J. Hart. (Institute of British Foundrymen : Foundry Trade Journal, 1948, vol. 84, Feb. 12, pp. 145–147). Considerations in pattern design and construction are discussed and the importance of close co-operation between the designer, the pattern-maker, and the foundryman is emphasized. An example of the benefits of such co-operation is provided by an account of two different approaches to the production of cast worm-drive casings.—J. R.

Use of Exothermic Cores in Pouring Stainless Steel. M. Beam. (Steel, 1948, vol. 122, Jan. 26, pp. 76–78). Examples of the successful use of exothermic materials in the production of stainless-steel and other types of heat- and corrosion-resisting castings at an electric-furnace foundry in California are illustrated and described.—J. R.

Transportable Electric Drying Machines. G. Manière. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 157–161). An account is given of an electric machine used in foundries for drying moulds. The machine is described and illustrated and the principle on which it operates is outlined.—J. C. R.

Permanent Moulds. J. B. McIntyre. (Metal Industry, 1948, vol. 72, Feb. 20, pp. 143–145). The author discusses materials now in use for permanent moulds and their disadvantages. He outlines the optimum requirements for refractory moulds and reviews the literature on this subject.—R. A. R.

The Manufacture of Some Large Castings for Marine Engineering. D. H. Young. (Institute of British Foundrymen : Foundry Trade Journal, 1948, vol. 84, Jan. 8, pp. 27–33 ; Jan. 15, pp. 59–63).

Rings, Pistons and Liners. (Automobile Engineer, 1948, vol. 38, Jan., pp. 27–39 ; Feb., pp. 51–61). A comprehensive account is given of the methods and machines employed by Hepworth and Grandage, Ltd. in the production of cast piston rings, pistons and cylinder liners.—R. A. R.

Conversion of Cylinder Cover from Floor to Machine Moulding. O. Smith. (Institute of British Foundrymen : Foundry Trade Journal, 1948, vol. 84, Feb. 19, pp. 177–179). Conversion of the production of cast cylinder covers from a floor to a machine-produced-mould operation is described. A more standard product was obtained by machine moulding and the cost of production was reduced by approximately 33⅓%. The cost of the pattern equipment was increased by 70%, but it was considered that this increased expense would be absorbed on the first batch of castings.—J. R.

Direct Rolling and Continuous Casting. E. Erni. (Von Roll Werkzeitung, 1948, vol. 19, Mar., pp. 64–68). The history of continuous casting and centrifugal casting is briefly reviewed with descriptions of machines developed by Bessemer, Hazelett, Trotz, Junghaus,

and Eldred for the former process, and that of Cammen for the latter.—R. A. R.

Lost-Wax Process for Castings. (Machines et Métaux, 1947, vol. 31, Nov., pp. 381–384). The lost-wax process is described with special reference to the Kerr Dental Manufacturing Company's practice.—R. F. F.

Commercial Possibilities of the Lost Wax Process. A. Short. (Journal of the Institution of Production Engineers, 1948, vol. 27, Feb., pp. 85–102). The lost-wax process is described, its further developments are indicated, and production costs of some castings are given together with particulars of production, limitations, and possibilities. The compositions of the wax, the sprayed coating, the solid refractory powder, or solid investment, and the bonding solution or liquid investment, are tabulated.—R. E.

Centrifugal Casting. Process Applied to Stainless and Carbon Steel Tubes. J. W. Moore and J. W. MacKay. (American Society of Mechanical Engineers : American Foundryman, 1948, vol. 13, Jan., pp. 41–49). *See* Journ. I. and S.I., 1947, vol. 157, Dec., p. 635.—R. A. R.

Centrifugal Casting Proves Advantageous for Iron Piston Rings. T. C. Jarrett and E. J. Hubbard. (Materials and Methods, 1948, vol. 27, Jan., pp. 79–82). The equipment and processes at a foundry producing centrifugally cast piston rings are described. An iron containing total carbon 3·20%, silicon 1·25%, manganese 0·66%, copper 0·55%, and molybdenum 0·50% is used ; it is melted in an induction furnace, and carefully weighed quantities are poured at 2650° F. into spinning moulds preheated to not higher than 600° F.—R. A. R.

An American Observes European Foundry Methods. R. E. Fisher, jun. (American Foundryman, 1948, vol. 13, Jan., pp. 51–53). An American's impressions of his visits to foundries in Great Britain, France, Belgium, Switzerland, and Czechoslovakia are recorded. —R. A. R.

Steel Foundry Practice at Penistone. T. Bishop. (Iron and Coal Trades Review, 1948, vol. 156, Feb. 20, pp. 369–374). A description is given of the steel foundries of David Brown and Sons (Huddersfield) Ltd., where high-frequency furnaces are used to produce the steel. Innovations include inspection by X-rays and gamma rays, vertical-axis centrifugal casting, and cement-sand moulding by the Randupson process.—R. A. R.

Mechanization Speeds Malleable Output. H. L. Day. (Iron Age, 1948, vol. 161, Feb. 5, pp. 64–69). An illustrated description is given of the malleable iron foundry of Auto Specialities Manufacturing Co., St. Joseph, Michigan.—R. A. R.

Pioneer Swedish Centrifugal Pipe Foundry. (Foundry Trade Journal, 1948, vol. 84, Mar. 4, pp. 219–221). Details are given of a new Swedish foundry for the large-scale production of centrifugally cast iron pipe, now in operation at the Oxelösund works of the A/B. Centrifugalrör. Brief outlines of the melting, annealing, and testing processes are included.—J. R.

Compressed Air in Foundries. H. J. Bullock. (Foundry Trade Journal, 1948, vol. 84, Feb. 26, pp. 203–205). Uses and equipment for compressed-air installations in foundries are discussed.—J. R.

Surface Defects in Steel Ingots. H. O. Howson. (Iron and Coal Trades Review, 1948, vol. 156, Mar. 5, pp. 475–481 ; Mar. 12, pp. 537–540). Various factors associated with the formation of ingot defects experienced in the production of solid wagon wheels and tyres forged from ingots cut into suitable blooms are discussed. Apart from the limitations imposed on ingot design by the dimensions of the finished products, it is considered that the chief cause of ingot defects is the rupture of the initial skin by a combination of ferrostatic pressure and contractional stresses.—J. R.

Identify Casting Defects. J. O. Vadeboncoeur. (American Foundryman, 1948, vol. 13, Jan., pp. 56–59). Methods of determining the cause of defects in castings are discussed, the defects being classified as inclusions, cylinder-bore defects, and those due to sand, gas, and shrinkage. One procedure is deliberately to exaggerate the conditions which are thought to have caused the trouble ; if the defects become increasingly apparent this proves that the presumed cause is correct.—R. A. R.

The Metallurgist in the Foundry. W. H. Salmon. (Institute of British Foundrymen : Foundry Trade Journal, 1948, vol. 84, Feb. 5, pp. 121–128, 132). Some fundamental principles and practices in foundry methods are explained and discussed.—J. R.

Control of Shrinkage Porosity in Castings. W. A. Baker. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 37–48). An account is given of the factors that cause shrinkage-porosity in castings and practical means of minimizing this defect.—J. C. R.

Foundry Research. A. Portevin. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 11–19). A review is presented of trends in present-day foundry researches.—J. C. R.

Some Considerations on Time Studies. C. Dennery. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 163–176). The application of time studies to foundry operations is discussed in detail.—J. C. R.

HEATING FURNACES AND SOAKING PITS

Gas Heating Speeds Seamless Tube Production. (Industrial Gas Times, 1947, vol. 10, July, pp. 310–316 ; Aug., pp. 346–350). The special gas-fired continuous heating installation used in the production of steel tubes at the Babock and Wilcox Tube Company's plant at Beaver Falls is described. The rated speeds of heating for the final sizing process are 50–150 ft./min. for 4-in. tubes, and 54–162 ft./min. for 6-in. tubes. The consumption of natural gas and other data are given.—R. A. R.

Heat Losses Through Furnace Walls. Molinié. (Congrès du Gaz, 1946, pp. 606–622 : [Abstract]. Chaleur et Industrie, 1948, vol. 29, Jan., p. 4D). Three methods are given for determining the heat accumulated in a furnace raised to its operating temperature, and the evaluation of losses by radiation, convection, and conduction is discussed. Means of reducing the relative importance of accumulated heat by the diminution of cooling during stoppages and by using light refractories are reviewed.—J. C. R.

Study of Variable Operating Conditions in Furnaces. V. Broida. (Chaleur et Industrie, 1947, vol. 28, Sept., pp. 221–230 ; Oct., pp. 256–264 ; Nov., pp. 279–290). The author presents a mathematical study of the heating and cooling curves for a furnace, and a calculation of the fuel consumption required to put it into operation. —J. C. R.

Soaking Pits. (Society of Furnace Builders : Journal of The Iron and Steel Institute, 1948, vol. 158, Jan., pp. 125–137).

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Controlled Furnace Atmospheres. (Industrial Gas Times, 1947, vol. 10, May, pp. 250–252). The theory of the use of hydrogen as a protective atmosphere in heat-treatment furnaces is explained, and methods of removing oxygen and moisture from hydrogen are described.—R.A.R.

Principles of Modern Heat Treating. R. M. Dyke. (Steel, 1948, vol. 122, Jan. 26, pp. 55–60, 62–64). In view of the development of heat-treatment processes and the stricter specifications for engineering steels, it is important that operatives should have an understanding of the physical and chemical transformations occurring. Detailed explanations are given of fundamental principles and practices of modern heat-treatment methods.—J. R.

Steel Processing Furnaces. E. B. Neil. (Steel Processing, 1947, vol. 33, Nov., pp. 696–702c). Heat-treatment furnaces of all kinds are described with details of the preparation, composition, and application of the special atmospheres designated *DX* (lean, *DX* (rich), *NX*, *RX*, Char-Mo, and *AX*.—R. A. R.

Gaseous Cementation. J. Pomey. (Chimie et Industrie, 1945, vol. 54, July, pp. 23–32; Aug., pp. 97–104). Previous works on gaseous cementation are reviewed. To study the mechanism of gaseous cementation, laboratory tests were carried out on bars of mild steel 11 mm. in dia., and 100 mm. long, using a porcelain tubular laboratory electric furnace, at a temperature of 930° C. for 3 hr. with a gas flow of 18 l./hr. These bars were quenched and weighed before and after treatment, and a Rockwell test taken. Suggestions are put forward for industrial practice.—R. F. F.

Cementation of Some Ferrous Alloys by Beryllium. J. Laissus. (Comptes Rendus, 1947, vol. 224, Mar. 10, pp. 742–743). The author has studied the diffusion of beryllium in a 13%-chromium stainless steel and in an 18/8 austenitic steel, with particular reference to the influence of temperature and duration of cementation, and surface hardness of the cemented alloys.—J. C. R.

Variable-Size Stress-Relieving Furnace. (Industrial Gas Times, 1947, vol. 10, Aug., pp. 332–334). A large stress-relieving furnace, designed so that its length is adjustable, is described (*see* Journ. I. and S.I., 1947, vol. 156, June, p. 311).—R. A. R.

The Heat Treatment of Wrought Steels in the Engineering Industry. E. Ineson. (Industrial Gas Times, 1947, vol. 11, Nov., pp. 33–36, 64; 1948, vol. 11, Jan., pp. 100–106, 112). The theory of transformations in steel on heating and cooling is explained by reference to the iron-carbon diagram and **S**-curves.—R. A. R.

Mechanical Handling in Heat Treatment Furnaces. D. B. Leason. (Industrial Gas Times, 1948, vol. 11, Jan., pp. 122–128; Feb., pp. 138–148). Mechanical devices for charging and discharging heat-treatment furnaces, and for moving the charge in furnaces, are described.—R. A. R.

Continuous Scale-Free Heat Treatment of Curtiss Electric Propeller Hubs. (Industrial Heating, 1947, vol. 14, Sept., pp. 1412–1422; Dec., pp. 1982–1990). An illustrated description is given of the continuous heat-treatment installation for the normalizing, hardening, and tempering of forged steel aeroplane propeller hubs at the Caldwell, New Jersey, plant of the Curtiss-Wright Corporation. The atmospheres in all heating and cooling chambers are controlled to minimize scaling.—C. O.

Lakeside Steel Improvement Co. Has Complete Heat Treating Facilities. (Industrial Heating, 1947, vol. 14, Nov., pp. 1905–1912; Dec., pp. 2067–2076). The heat-treating furnaces and testing equipment at the works of the Lakeside Steel Improvement Co., Cleveland, Ohio, are described.—R. A. R.

Direct Heating Resistance Electric Furnaces. V. Paschkis. (Industrial Heating, 1947, vol. 14, Dec., pp. 2002–2006). The changes in temperature distribution, and some factors affecting it, in a charge heated by passing a heavy current through it are discussed.—R. A. R.

Effect of the Heating Rate of the Steel on the Pearlite-Austenite Transformation with Special Reference to Surface Hardening. W. Eilender and R. Mintrop. (Stahl und Eisen, 1948, vol. 68, Feb. 26, pp. 83–85). Investigations on the heating of 0·54% carbon steel showed that the pearlite-austenite transformation point was raised considerably by high rates of heating. In induction hardening, with its very rapid heating rate and a short holding time at above the A_3 point, the normal hardening temperature may be considerably increased. The effect of the initial structure and the formation of austenite from a ferrite-cementite structure, are also discussed.—R. A. R.

The Influence of Heat Treatment on the Hardness and Structure of a Cr–Si Valve Steel. H. Dinner and W. Felix. (Sulzer Technical Review, 1947, No. 1, pp. 21–27). A chromium–silicon valve steel was submitted to various heat-treatments and tested as to hardness and structure. The results of the metallographic investigations, extended to include microhardness tests, led to the following conclusions: The hardenability of the steel increases with rising temperature as a result of the increasing dissolution of the special carbides in the γ-iron. For the same reason the steel inclines to overhardening at high temperatures with sudden quenching, and soft residual austenite then appears in increasing quantities together with martensite in the structure. Overhardening can be counteracted by the employment of mild quenching media. In the tempering process the martensite of the hardening structure decomposes and becomes troostite while eliminating the carbon held in forced solution. The residual austenite only changes to martensite during the subsequent cooling, after a preliminary impoverishment of carbon. A second tempering permits the martensite produced from the residual austenite to be transformed in its turn into tempered troostite.—R. A. R.

Oxyacetylene Surface Hardening of Cast Iron. E. Daynié. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 87–96). The principle and methods of flame-hardening are outlined and the equipment used is described. It is shown that this treatment can be applied to pearlitic cast irons, but is not suitable for martensitic or ferritic cast irons. The cast iron should not be porous or contain blowholes, and its carbon content should be about 3%, of which 0·7% to 0·9% should be combined. The precautions to be taken are outlined and the application of the process in the manufacture of lathe beds is described.—J. C. R.

Flame-Hardening Machine Tool Parts. W. D. Whalen. (Welding Journal, 1948, vol. 27, Jan., pp. 11–18). A comprehensive account is given of methods of flame-hardening machine-tool parts with descriptions of the machines and equipment for routine and special jobs.—R. A. R.

Surface Flame Hardening. F. Lavaur. (Métaux, Corrosion, Usure, 1943, vol. 18, Feb., pp. 39–42). Three methods of flame-hardening are discussed, namely, local hardening, hardening of large pieces in sections, and simultaneous hardening of the whole surface.—M. A. V.

Sub-Zero Treatment of High Speed Steels. Colombier. (Centre de Documentation Sidérurgique, Circulaire d'Informations Techniques, 1947, vol. 4, Apr. 25, No. 6, pp. 37–42). A review is presented of the work of various investigators on the influence of sub-zero treatment (−85° C. to −190° C.) on the structure and properties of high-speed steels.—J. C. R.

Induction Heating Triples Die Life. J. M. Butler. (Steel, 1948, vol. 122, Jan. 19, pp. 98–100). An account is given of the performance of induction-heating units

operating in conjunction with a 1500-ton forging press. Complete uniformity of heating has been achieved, together with an almost scale-free surface, and die life has been greatly increased.—J. R.

The Present Position of High-Frequency Heat Treatment in France. P. Partiot. (Métallurgie, 1948, vol. 80, Jan., pp. 11, 13). A brief note is presented on the hardening of steel parts by high-frequency heat-treatment.—J. C. R.

High Frequency Heat-Treatment. J. Blandin. (Métallurgie, 1947, vol. 79, Nov., pp. 31–33 ; Dec., pp. 19–21). The first part of this article deals with generators for electronic and induction heating ; and the second part deals with the effect on the structure of the treated metal and the industrial applications of this method of treatment.—J. C. R.

High-Frequency Heating—Developments in Standard Equipment for a Wide Range of Applications. (Automobile Engineer, 1948, vol. 38, Feb., pp. 69–71).

The Surface Hardening of Steel by Heating with High Frequency Induction Currents. G. Perronne. (Revue Générale de l'Électricité, 1947, vol. 56, Oct., pp. 412–420 : Electrical Engineering Abstracts, 1948, vol. 51, Jan., p. 21). The theory and practice of induction-hardening are described. Electrical, thermal, and metallurgical problems are discussed. Finally, a description of the electric plant necessary is given and results compared with surface hardening by other processes.

Spray Quench Speeds Induction Hardening. F. W. Curtis. (Machinist, 1948, vol. 91, Feb., pp. 1421–1423). The heat-treatment of sprocket teeth, crankshafts, hair-clipper blades, trimmer blades, pliers, shear blades, and rocker-arm ends, is briefly described and illustrated. —R. L. B.

Annealing Ovens—Equipment and Practice for Malleable Iron. J. H. Lansing. (American Foundryman, 1948, vol. 13, Jan., pp. 38–40). The different types of furnaces and the time-temperature cycles for annealing malleable iron are reviewed.—R. A. R.

Cyclic Annealing of Steel Forgings Saves Time, Betters Quality. K. Rose. (Materials and Methods, 1948, vol. 27, Jan., pp. 71–74). Details are given of the annealing cycles for chromium–nickel and chromium–nickel–molybdenum steels developed by some of the American automobile manufacturers.—R. A. R.

Rapid Annealing of Malleable Iron Castings. G. Joly. (Fonderie, 1947, Oct., pp. 857–860 ; Foundry Trade Journal, 1948, vol. 84, Feb. 26, pp. 200–202). The disadvantages of the usual equipment and methods employed in France for the batch annealing of malleable-iron castings are enumerated, and modern developments are reviewed with reference to the practice and conditions obtaining. It is considered that in view of the high cost of electric current the French foundryman tends towards the use of small-capacity furnaces fired by the cheaper fuels, and suggestions for improvements are discussed.—J. R.

Attempts to Prevent Temper Brittleness. F. Bleilöb. (Berg- und Hüttenmännische Monatshefte der Montanistischen Hochschule in Leoben, 1947, vol. 92, Dec., pp. 204–211). An investigation is described the object of which was to develop an interrupted quench hardening treatment which would considerably reduce, or entirely prevent, temper brittleness. Heat-treatments were developed for steels alloyed with : (1) Silicon–manganese ; (2) manganese–vanadium ; (3) chromium–vanadium ; (4) chromium–aluminium ; and (5) manganese. Details of the treatments for bars of different sizes are given. —R. A. R.

Martensitic Quenching of Cast Irons. G. Halbart. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 49–55). The author considers the influence of silicon, carbon, manganese, oxygen, the period of heating before quenching, and the rôle of phosphorus on the water-quenching of plain cast irons.—J. C. R.

FORGING, STAMPING, DRAWING, AND PRESSING

The Works Metallurgist in the Drop-Forging Industry. F. E. Stokeld. (Journal of the Birmingham Metallurgical Society, 1947, vol. 27, Dec., pp. 395–410). The scope of the activities of the works metallurgist in regard to drop-forging non-ferrous metals and steel is reviewed with notes on checking the quality of raw material, water-quenching, and the prevention of overheating. —R. A. R.

A Theoretical Analysis of the Stresses and Strains in Extrusion and Piercing. R. Hill. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., pp. 177–185).

German Chain Link Fencing and Wire Netting Industry. (British Intelligence Objectives Sub-Committee, 1948, Final Report No. 1693 : H.M. Stationery Office).

Cold Forgings. C. J. Whitcombe. (Journal of the Institution of Production Engineers, 1948, vol. 27, Jan. pp. 23–42). The author considers the production from wire, of parts such as nails, screws, and bolts and nuts, by cold forging. The principles of cold forging are outlined and the scope of the process and the diverse objects which can be produced are briefly discussed. —R. E.

The Production of Forgings for Radial and Jet Aircraft Engines at Canton Drop Forging Plant. (Industrial Heating, 1947, vol. 14, Nov., pp. 1800–1810, 1933 ; Dec., pp. 1972–1980, 2076). The equipment used for the forging and heat-treatment of radial engine cylinders for aircraft at the works of the Canton Drop Forging and Manufacturing Co., Canton, Ohio, is described in Part I of this series, whilst Part II deals with the production of crankcases and rotors.—R. A. R.

The Extrusion Molding Process. H. B. Cook. (Iron Age, 1948, vol. 161, Jan. 29, pp. 62–69 ; Feb. 5, pp. 79–86, 134). The machines and dies for producing parts, mostly of non-ferrous metals, by extrusion moulding are described. An application of particular importance is the manufacture of gas turbine components. —R. A. R.

Economical Short Run Stamping Dies. W. G. Patton. (Iron Age 1948, vol. 161, Feb. 19, pp. 84–86). The Ford Motor Company has produced a series of low-melting-point alloys called "Cerrobend," "Cerrosafe," "Cerromatrix," etc., consisting of bismuth, lead, tin and cadmium, which, when chilled in liquid nitrogen, can be used for dies for experiments in stamping sheet metal. The properties of these alloys and their advantages are described.—R. A. R.

The Practical Aspects of Metal Spinning. R. J. Schneider. (Iron Age, 1948, vol. 161, Feb. 12, pp. 76–80, 133, 134). The tools, technique, advantages, and limitations of the process of metal spinning are discussed.—R. A. R.

An Automatic Tube Mill Employing Gas Processing. A. C. Jennings. (Engineers' Association : Industrial Gas Times, 1948, vol. 11, Mar., pp. 161–167). An illustrated description is given of the sequence of processes in the manufacture of seamless steel tube using a fully automatic push bench. In this process the pierced billet is pushed through a series of ring dies held in a cast steel trough 44 ft. long ; these reduce the outside diameter to the required size ; the bore size remains practically unchanged.—R. A. R.

Steel Tubing and Plate Replaces Castings in Heavy-Duty Parts. K. Rose. (Materials and Methods, 1947, vol. 26, Dec., pp. 68–70). A method of making railway draw-bar equipment by shaping and welding steel tubes and plate is described. The finished parts are very much lighter than when made of castings.—R. A. R.

Practical Design of Thin-Metal Stampings. W. C. Mills. (Machinist, 1948, vol. 91, Jan. 24, pp. 1317–1320). Because of the tearing and wrinkling tendencies during forming, special production techniques and forming-die designs are required for deep-drawing thin metals. Typical basic operations are illustrated, and suggestions for design of decorative stampings, and hints on the design of tin-can seams are put forward.—R. L. B.

Difficult Forming Problems Solved with the Metal Stretching and Shrinking Machine. R. Smith. (Sheet Metal Industries, 1948, vol. 25, Jan., pp. 131–134, 142). A detailed description is given of a stretching and shrinking machine for forming sheet metal. Flanges can be raised on a sheet having a curved edge without wrinkling it as provision is made for the metal to increase in thickness.—R. A. R.

Strain Gage Analysis of Mechanical Punch Presses. G. Brewer. (Iron Age, 1948, vol. 161, Jan. 15, pp. 66–72). Dynamic and static tests by means of strain gauges on mechanical punch presses are described. Some results are presented, and improvements in design which they suggest are considered.—R. A. R.

Press Forgings. (Automobile Engineer, 1947, vol. 37, Dec., pp. 493–497). In these notes the benefits to be gained through employment of press forgings are briefly discussed. One make of high-speed forging press, the Eumuco " Maxima " press, is described. Finally, details are given of some automobile applications.—R. A. R.

Drawing Auto Engine Rocker Arm Covers. T. E. Lloyd. (Iron Age, 1948, vol. 161, Jan. 15, pp. 84–86). A 400-ton press and the dies for deep-drawing steel sheet to make automobile rocker-arm covers are described. —R. A. R.

Forging Die Design—Swaging. J. Mueller. (Steel Processing, 1947, vol. 33, Nov., pp. 673–676). Descriptions are given of dies used in swaging machines and some of the operations performed with them.—R. A. R.

Future Trends in Machinery and Dies for the Wire Trade. N. Davidson. (Wire Industry, 1948, vol. 15, Jan., pp. 37–41).

The Present State of Knowledge of the Mechanics of Wire Drawing. E. Siebel. (Iron and Steel Institute, 1948, Translation Series, No. 334). This is an English translation of a paper which appeared in Stahl und Eisen, 1947, vol. 66–67, May 22, pp. 171–180 (*see* Journ. I. and S.I., 1947, vol. 157, Sept., p. 146).—R. A. R.

Experience in Drawing Fine Steel Wires at High Drawing Speeds. C. Eisenhuth. (Stahl und Eisen, 1948, vol. 68, Jan. 29, pp. 46–48). A report is presented on tests with different wire-drawing machines for drawing hard steel wire less than 0·7 mm. in dia. Particulars of the performance of machines producing wire 0·45 and 0·37 mm. in dia. at average speeds of 7·78 and 7·75 m./sec. respectively, are given.—R. A. R.

Crucible Modernizes Wire Mill. J. Anthony. (Iron Age, 1948, vol. 161, Jan. 29, pp. 70–73). New equipment at the wire works of the Crucible Steel Company of America is described and illustrated. It includes pickling, annealing, and continuous-wire-grinding machinery as well as high-speed draw benches.—R. A. R.

Drawing Special Types of Industrial Wire. (Steel, 1948, vol. 122, Feb. 2, pp. 98–100, 114). The processes developed by the Keystone Steel and Wire Company for producing wire for wire ropes and musical instruments to very exacting specifications are described.—R. A. R.

ROLLING-MILL PRACTICE

Rolling Mill Conversion. (Electrical Review, 1948, vol. 142, Feb. 20, pp. 267–270). The conversion from steam to electrical operation of the rolling-mill drives at two steelworks on the North East Coast is described and illustrated.—R. A. R.

Rolling-Mill Calculations. L. R. Underwood. (Institution of Mechanical Engineers : Iron and Coal Trades Review, 1948, vol. 156, Feb. 27, pp. 437–441). Empirical, semi-empirical and rational methods developed from first principles of roll-load and power calculation in rolling mills are discussed with examples.—R. A. R.

Graphical Methods for Calibrating Mill Rolls. L. Wasutowski. (Hutnik, 1947, vol. 14, Apr., pp. 206–219). [In Polish]. The theoretical foundation for the graphical method of calibrating the rolls for rolling mills is given with some examples of graphs for different rolling-mill products.—W. J. W.

Graphic Roll Calibration. G. Wallquist. (Jernkontorets Annaler, 1948, vol. 132, No. 2, pp. 27–41). [In Swedish]. In roll calibration the calculations can be based upon certain linear dimensions of the different passes instead of on area relationships. This paper presents the author's graphic method of roll-pass design as applied to some very common types of rolling, *e.g.*, rolling billets in diamond passes, and rounds in alternating square and round passes. The principle of the calibrations for rolling squares, hexagons, octagons, and other simple sections is also described.—R. A. R.

Some Problems in Rolling. H. Ford. (Swansea and District Metallurgical Society : Iron and Steel Institute, 1948, Special Report No. 39, pp. 7–27). A better understanding of the mechanism of deformation in the rolling process is an important factor in improving the design and operation of mills. The latest theory of the deformation process—that due to Orowan—is discussed in relation to previous theories and conceptions, and compared with experimental results of rolling tests. An attempt is made at a simple elucidation of the theory as it applies to practical conditions of hot and cold rolling. The results show that for cold rolling, the simple theory of Ekelund gives values of roll force which agree very closely with those obtained by Orowan's theory, while both can be made to agree reasonably well with experimental values under certain conditions. In hot rolling, there is insufficient experimental evidence from which to draw conclusions as to the applicability of the new theory, but it would appear to be a definite advance on previous ideas. The paper concludes by discussing a few general problems affecting mill output and the quality of the product.

Some Notes on Rolling-Mill Practice. G. Foster. (Cleveland Institution of Engineers : Iron and Steel Institute, 1948, Special Report No. 39, pp. 49–58). The paper is not intended to be an advanced treatise on rolling-mill practice, but rather an outline of principles employed in the rolling of shaped sections. The author hopes that the paper may help steelworks personnel who are not actively connected with rolling mills to appreciate some of the difficulties involved.

The paper commences with a brief description of the stages in an ingot's journey through a section rolling mill. Abnormalities in the heating of ingots are discussed, together with their effect on cogging-mill practice. Difficulties encountered in the production of blooms are discussed at some length. The principles employed in the production of some of the more common structural shapes are considered, and various methods of producing the same shape are compared. In particular, the advantages and disadvantages of each of two rival methods of

producing joists are outlined. The final section of the paper is devoted to a description of some rolling-mill guides.

Merchant-Bar and Wire-Rod Mill at the Dalzell Steel Works, Motherwell. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., pp. 254–256).

Defects and Imperfections in Steel Sheets. Z. Wusatowski. (Hutnik, 1946, vol. 13, Dec., pp. 620–630). [In Polish]. Different kinds of defects occurring in the manufacture of thin and thick sheets and means of preventing them, are discussed. Many photographs of commonly occurring defects are shown.—W. J. W.

Reversing and Tandem Cold Mills. M. D. Stone. (United Effort, 1948, vol. 28, Jan., pp. 3–9). The development of cold-rolling mills is traced from the earlier recorded mills to the modern 4-high reversing and tandem mills, and some of the more noteworthy mills described. The technical and economic factors affecting the choice of the type of mill for particular products are discussed ; it is concluded that the reversing mill is more flexible and requires less capital expenditure, whilst the tandem mill is more cheaply operated and has greater production.—M. A. V.

MACHINERY FOR IRON AND STEEL PLANT

Maintenance of Industrial Electrical Plant. J. L. Watts. (Iron and Coal Trades Review, 1948, vol. 156, Feb. 27, pp. 427–431). A scheme for the maintenance of industrial electrical plant is outlined. It covers ball, roller, and sleeve bearings ; brushes, slip rings, and commutators ; motor windings ; short circuit troubles ; resistance testing ; motor-control gear ; and flexible cables and earthing systems.—R. A. R.

Five Modern Boilers Will Replace Forty-Six Old Ones in Steel Plant. F. X. Gilg. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 108–111). Details are given of a proposed new boiler plant at the Southside Works of the Jones and Laughlin Steel Corporation. The new installation will consist of five modern Stirling boilers each capable of generating 200,000 lb. of steam per hour ; it will replace 46 boilers at present in use.—J. R.

High Pressure Steam Generation. A. J. Bousfield. (Engineering and Boiler House Review, 1948, vol. 63, Feb., pp. 40–48). Experience gained in the operation and maintenance of the 60,000-kW. power station at the Ford Works at Dagenham is related. There are three high-pressure boilers of the Babcock & Wilcox sectional header type. The operating conditions are : Steam pressure 1250 lb./sq. in., steam temperature 750° F., and feed-water temperature 380° F. Experience has proved that : (1) The use of extra-high-pressure steam for extraction turbines of 30,000 kW. and over is an economical proposition ; (2) The extra-high pressure is practical from a maintenance point of view ; (3) the boilers and turbines can be run for long periods continuously ; (4) that extraction steam is a solution to the problem of factory and other heating, especially where the condensate can be returned in a pure condition to the power house.—R. A. R.

Electrical Developments in the Steel Industry during 1947. H. W. Poole. (Blast Furnace and Steel Plant, 1948, vol. 36, Jan., pp. 76–82). Details are given of electrical equipment recently installed in, or under construction for, American and foreign steelworks. —J. R.

A Fabricated Heavy Plate Bending Machine. H. B. Fergusson, R. V. Rowles, and N. A. Graveson. (Engineer, 1948, vol. 185, Feb. 27, pp. 214–215). An abridged description is given of a plate-bending machine, almost entirely of welded construction, capable of bending 3½ in. thick plates in the cold state. The force is applied to the vertical bending die by means of three pairs of wedges sliding on roller assemblies.—R. A. R.

LUBRICANTS AND LUBRICATION

Lubricant in Deep Drawing. A. H. Stuart. (Light Metals, 1948, vol. 11, Jan., pp. 45–48). The advantages of colloidal graphite as a lubricant in deep-drawing are explained.—M. A. V.

Fundamental Work on Friction, Lubrication and Wear in Germany. (British Intelligence Objectives Sub-Committee, 1948, Final Report No. 1610 : H.M. Stationery Office). Fundamental research on friction and lubrication carried out in Germany from 1939 to 1945 is reviewed. Much work of great interest and importance was carried out. Zorn's tests showed that the introduction of certain radicals and specific side chains in the molecule had a profound effect on pour point, viscosity, and lubricating properties. He was able to select and manufacture synthetically lubricants which compared favourably with the best natural lubricants.—R. A. R.

Antifriction Bearings. L. E. Browne. (Steel, 1947, vol. 121, Nov. 17, pp. 90–91, 126–128 ; Dec. 1, pp. 88–89, 114–120 ; Dec. 15, pp. 96–102 ; Dec. 29, pp. 50–53 ; 1948, vol. 122, Jan. 12, pp. 72–74, 100 ; Jan. 26, pp. 50–53, 73). In this series of articles Part I deals with the fundamental principles of bearing practice, Part 2 with bearings for high-precision machine tools, Part 3 with needle bearings, Part 4 with bearings for rolling stock, and Part 5 with ball bearings for high-speed machines in several industries.—R. A. R.

Test on Tars as Hot-Rolling-Mill Lubricants. (Revue de Métallurgie, 1946, vol. 43, July–Aug., p. 235). Tars suitable for rolling-mill bearings must have a softening point of the order of 114° to 122° C. and the variation in the " Ubbehlode drop test " must be slight. The spreading coefficient must be between 1·6 to 2·4. Coal and petroleum tars were tested, but only petroleum tars proved satisfactory.—R. F. F.

The Concept " Oiliness as Load-Carrying Capacity." E. Heidebroek. (Archiv für Metallkunde, 1947, vol. 1, July–Aug., pp. 356–359). The objects to be achieved by lubrication are discussed in an endeavour to arrive at a definition of " oiliness," and the static and dynamic loads which lubricants can carry are considered.—R. A. R.

WELDING AND FLAME-CUTTING

Welding *versus* Casting and Riveted Structures. J. G. Noble. (Journal of the Institution of Production Engineers, 1948, vol. 27, Jan., pp. 19–22). The advantages of welding over riveted work and castings are pointed out, and some indications are given of the main factors controlling costs.—R. E.

Production Time Cut by Arc Welding Thin Tubing. (Machinist, 1948, vol. 91, Jan. 24, pp. 1326–1327). Improvements in the mass production of automobiles and their parts, aircraft petrol tanks, and ships' anchor chains are mentioned and illustrated. Increased production is experienced by having the conveyor at the correct working height.—R. L. B.

Some Thermodynamical Aspects of the Formation of Inclusions in Mild-Steel Weld Metal. E. C. Rollason and E. Bishop. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., pp. 161–168).

Hydrogen in Welds. Causes and Effects. F. Meunier and J. Sébille. (Société Française de Métallurgie : Revue de Métallurgie, 1947, vol. 44, May–June, pp. 180–186). The causes and effects of hydrogen in steel welds are reviewed.—R. F. F.

Quenching Effect during the Welding of Steels. H. Granjon. (Société Française de Métallurgie : Revue de Métallurgie, 1947, vol. 44, May–June, pp. 187–192). Experimental methods for the study of the behaviour of steels during oxy-acetylene and arc welding, devised by the Institut de Soudure Autogène, are described. Results are given for tests carried out on 10-mm. sheets of plain and alloy steels.—R. F. F.

Multiple Flame Pressure Welding Process. N. H. Cuke. (Welding Journal, 1948, vol. 27, Jan., pp. 39–47). A detailed description is given of an oxy-acetylene welding process for joining the edges of sheets or plates. The edges to be joined are kept apart while heat is applied by means of a long row of small flames from a water-cooled burner head. The metal is heated to fusion point, the burner is lifted, and mechanical pressure is applied to force the edges together. The welding machines are described and test data on the joints are presented.—R. A. R.

High-Speed Oxyacetylene Tube Welding. H. O. Jones. (Welding Journal, 1948, vol. 27, Jan., pp. 25–26). A process, similar to the Fretz-Moon process, for making light steel tubing at high-speed is described and data on the consumption of acetylene and oxygen are given.—R. A. R.

Open-Butt Pressure Welding of Steel. H. R. Clauser. (Materials and Methods, 1948, vol. 27, Jan., pp. 83–86). A description is given of a process of butt-welding bar, tubes, and rails, in which an oxy-acetylene burner head, projecting flames on both sides, is placed between the surfaces to be welded. When fusion point has been reached the burner is quickly withdrawn and the ends are forced together by mechanical pressure to complete the weld.—R. A. R.

ESAB's Semi-Automatic Welding Machine. G. Hancke. (Svetsaren, 1947, vol. 12, No. 3, pp. 65–75). [In Swedish]. A detailed description is given of a simple and inexpensive semi-automatic electric welding device developed by Elektriska Svetsningsaktiebolaget. It consists of two stands each with a pivoted arm carrying a welding electrode. The stands are placed in tandem along the seam to be welded, in such a manner that the first electrode will, before it is entirely consumed, ignite the second one. While the second one is melting, a new electrode is fitted into the first stand which is then moved into position behind the second. Heavy gauge electrodes with thick coatings are used. The arc is maintained continuously for the whole length of the weld and efficient deposition in relation to current consumption is obtained.—R. A. R.

Short-Cut Estimation of Welded Process Vessels. H. How. (Chemical Engineering, 1948, vol. 55, Jan., pp. 122–126). Charts are presented for calculating the cost of making unfired pressure vessels. These charts show the time required for performing various operations such as oxy-acetylene cutting, machining, edge preparation, flanging and welding plates of different sizes and thicknesses.—R. A. R.

A Study of Projection Welding. W. F. Hess and W. J. Childs. (Welding Journal, 1947, vol. 26, Dec., pp. 712-s–723-s). Projection welding is a form of spot welding in which one of the components is provided with projections at the points to be welded ; these are pressed flat during the operation. An investigation is reported in which the effects of projection size, welding time, mechanical pressure, and welding current on the properties of the weld were determined.—R. A. R.

Electric Arc Stud Welding. R. C. Singleton. (Welding Journal, 1947, vol. 26, Dec., pp. 1095–1101). A description is given of the Nelson stud-welding pistol for the semi-automatic welding of steel studs on to plates. The process is as follows : The stud is loaded into the chuck forming the barrel of the pistol, a ferrule containing a flux is placed on the end of the stud, and this is then held against the plate. The trigger is pressed to switch on the current and a solenoid coil lifts the stud, creates an arc, and forms a pool of metal on the plate and the end of the stud. When the preset arcing period is completed the welding current and the solenoid are cut out, and the main spring of the pistol pushes the stud against the plate. Data on the strength of the welds are presented. —R. A. R.

Point Diameter and Electrode Pressure in the Electric Spot-Welding of Steel Sheets. F. Rosenberg. (Werkstatt und Betrieb, 1947, vol. 80, Dec., pp. 293–296). Factors affecting the tip radius of spot-welding electrodes and the mechanical pressure required for optimum results in the welding of steel sheets of different thicknesses are considered.—R. A. R.

Instruments for the Measurement of the Main Variables in Resistance Welding Machines. (Welding Research, 1947, vol. 1, Dec., pp. 19–24). This is the First Interim Progress Report of the FR.5 Committee of the British Welding Research Association studying the development of devices for measuring current, pressure, and time in resistance welding machines. Considerable progress has been made in developing instruments for measuring secondary current and welding time. The instruments for these purpose are called the " impulse ammeter " and the " cylegrapher " respectively.—R. A. R.

The " Aga " Deep-Welding Technique. R. Gunnert. (Lastechniek, 1948, vol. 14, Jan., pp. 1–6). [In Dutch]. A description is given of an oxy-acetylene welding technique in which the flame heat is efficiently utilized by keeping the flame well down between the edges to be welded.—R. A. R.

Design of Arc-Welded Steel and Its Relation to Costs. R. H. Davies. (Welding Journal, 1947, vol. 26, Dec., pp. 1087–1090). Factors to be taken into account in the design of welded beams and welded machine-tool bases and stands, and the differences between designing for cast and for welded construction are considered. —R. A. R.

Submerged Melt Welding of Hardenable Steels. E. A. Clapp and E. L. Frost. (Welding Journal, 1947, vol. 26, Dec., pp. 1079–1082). Particular emphasis is placed on the control of cooling rates of welded assemblies as affected by preheat temperatures and welding conditions. It is pointed out that isothermal-transformation-curve data can be used to determine proper preheat and postheat temperatures to facilitate the welding of hardenable steels. Penetration and dilution factors are controlled in this automatic welding process by welding speeds and currents which can be varied over a wide range. —R. A. R.

Radiographing and Controlled Low-Temperature Stress Relieving of Welded Tanks for Wet Seal Gas Holder. R. Kraus. (Welding Journal, 1947, vol. 26, Dec., pp. 1073–1079).—R. A. R.

Effect of Manganese and Molybdenum on the Microstructure and Mechanical Properties of Low-Alloy Ferritic Weld Metal. W. G. Benz, jun. (Welding Journal, 1947, vol. 26, Dec., pp. 742-s–748-s). This report presents the results of an investigation of the effect of manganese and molybdenum on the microstructure, hardness, impact values, and tensile strength of weld metal deposited with lime-ferritic electrodes.—R. A. R.

Some Factors Controlling the Ductility of 25% Cr–20% Ni Weld Deposits. O. R. Carpenter and N. C. Jessen. (Welding Journal, 1947, vol. 26, Dec., pp. 727-s–741-s). The effects of varying the contents of carbon, manganese, and silicon in lime-coated 25/20

chromium–nickel electrodes on the properties of welds were investigated. The optimum carbon content was 0·12–0·20%. More than about 0·50% of silicon with carbon 0·12% or less caused defective welds. The addition of molybdenum and columbium appeared to reduce the formation of microcracks in the 0·505-in. dia. specimens.—R. A. R.

Types of Modern Wire Welding Equipment. (Wire Industry, 1947, vol. 14, Oct., pp. 565–568; Nov., pp. 621–624; Dec., pp. 679–681). Illustrated descriptions are given of a variety of general-purpose and specialized machines for the welding of wire.—C. O.

How to Select Mild Steel Arc Welding Electrodes. H. O. Westendarp, jun. (Steel Processing, 1947, vol. 33, Nov., pp. 679–680, 703). The manner in which the following welding conditions affect the selection of the electrode is considered: (1) Position in which welding must be done; (2) power supply to arc; (3) fit of the joint; (4) plate thickness; (5) skill of operator; and (6) rating of generator.—R. A. R.

German Arc Welding Electrodes and Their Manufacture. (Combined Intelligence Objectives Sub-Committee, 1948, Report No. XXXIII-12: H.M. Stationery Office).

Welding Techniques for Cast Iron. T. E. Kihlgren. (Welding Journal, 1948, vol. 27, Jan., pp. 19–25). Techniques for electric welding cast iron, using nickel or nickel–copper electrodes, are described, and numerous examples are illustrated.—R. A. R.

The Arc Welding of Highly Stressed Steel Parts in Aeroplane Manufacture. A. Svensson. (Svetsaren, 1947, vol. 12, No. 2, pp. 31–41). [In Swedish]. Details are given of the welding technique used for welding chromium–molybdenum steel components for highly stressed parts in aeroplanes.—R. A. R.

The Fabrication of a Mild Steel Cylinder Block. C. Drewry. (New Zealand Engineering, 1947, vol. 2, Nov. 10, pp. 1151–1152). At a time when it was impossible to obtain new parts for a Diesel locomotive it was necessary to fabricate two 2-cylinder blocks. A description is given of how this was done using 5-in. dia. steel tubes subsequently fitted with cast iron liners, top and bottom plates of $\frac{5}{8}$-in. mild steel, $\frac{3}{16}$-in. steel for the water jacket, and standard steel elbows for the inlet and exhaust parts.—R. A. R.

Resistance Welding in Mass Production. A. J. Hipperson and T. Watson. (Welding, 1948, vol. 16, Feb., pp. 76–80). The electrodes and jigs used in electric hot-riveting processes are described.—R. A. R.

Time Studies in Welding. S. Rassmuson. (Svetsaren, 1947, vol. 12, No. 2, pp. 42–53).

The Plasticity and Pressability of Coating Materials for Welding Electrodes. W. Hummitzsch. (Berg- und Hüttenmännische Monatshefte der Montanistischen Hochschule in Leoben, 1947, vol. 92, Dec., pp. 211–221). The factors affecting the plasticity of the mixtures used for coating welding electrodes are examined and the effects of additions of china clay and waterglass are shown. The Brabender plastograph for determining plastic properties is described and data on plasticity and the relation between the pressing force required and the plasticity are presented.—R. A. R.

Town Gas for Metal Cutting. (Coke and Gas, 1948, vol. 10, Jan., pp. 31–32). Some modern designs of oxygen-cutting and profiling machines utilizing town's gas are described and illustrated, and an indication of their performances is given.—J. R.

Review of Flame Cutting Developments Past, Present, and Future. R. E. Doré. (Transactions of the Institute of Welding, 1948, vol. 11, Feb., pp. 25–34).

Making the Most of Oxygen Cutting. C. G. Bainbridge. (Iron and Coal Trades Review, 1948, vol. 156, Jan. 30, pp. 205–211). Practical and economic considerations in the oxygen cutting of steel are discussed in the light of experience of the industrial use of various types of equipment. Operating notes and data are presented.—J. R.

Underwater Cuttings. (British Engineering Export Journal, 1948, vol. 30, Jan., pp. 988–989). The applications of the oxy-hydrogen underwater cutting process are briefly discussed and the general arrangement of the B.O.C.-Siebe Gorman cutter is shown.—R. E.

MACHINING AND MACHINABILITY

Band Saw Blading. H. J. Chamberland. (Steel, 1948, vol. 122, Jan. 19, pp. 66–67, 104). A great increase in the number of applications of band-sawing has taken place during recent years, and by 1946 some 200 basic materials and their derivatives were being economically processed by that method. Factors contributing to this development are outlined and various types of band-saw blading are discussed.—J. R.

Materials Used in America for the Cutting Edge of Milling Tools. J. Doumenach. (Machines et Métaux, 1947, vol. 31, Apr., pp. 121–124; May, pp. 156–160). The properties, uses, and composition of American steels are described and the deposition of special steel coatings with the oxy-acetylene torch, and the heat-treatment of the steels are reviewed.—R. F. F.

The Economic Importance of the Hard Metals. J. Witthoff. (Archiv für Metallkunde, 1947, vol. 1, July–Aug., pp. 316–318). The advantages of using hard-metal cutting tools are discussed with special reference to their place in German industry.—R. A. R.

Manufacture and Application of Sintered Carbides. Part I—Production and Properties. E. Trent. **Part II—Application in Industry.** H. Eckersley. (Journal of the Institution of Production Engineers, 1947, vol. 26, Oct., pp. 349–377). The nature, production, and properties of cemented carbides are discussed and the applications of carbide tools in the engineering industry are shown.—R. E.

Machining Castings. A. O. Schmidt. (American Foundryman, 1947, vol. 12, Nov., pp. 22–27). Methods of assessing the ability of steel and carbide tools to machine castings are briefly discussed. An apparatus for the calorimetric determination of tool forces during machining is described, and mention is made of the effects of cutting speed, rake and clearance angles, and blade arrangement.—C. O.

German Hand Tools Industry—Files and Rasps. (British Intelligence Objectives Sub-Committee 1947, B.I.O.S. Final Report No. 1628 (Section 1): H.M. Stationery Office).

Emulsifying Agents for Metalworking. P. D. Liddiard. (Metal Treatment, 1947, vol. 14, Winter Issue, pp. 241–242). German practice in the manufacture and use of lubricants and cutting oils required for the severe deformation of metals is reviewed.—R. A. R.

Soluble Oils for Cutting and Grinding Operations. C. M. Larson. (Iron and Steel Engineer, 1947, vol. 24, Nov., pp. 73–77). The three types of soluble-oil emulsions are classified and their uses in cutting and grinding operations are indicated. The author considers that the wider application of such cutting fluids is restricted because of their relatively high power loss and certain lubrication difficulties.—C. O.

CLEANING AND PICKLING

Fundamental Aspects of Metal Cleaning. J. C. Harris. (American Ceramic Society Bulletin, 1947, vol. 26,

Dec. 15, pp. 389–392). The forces causing undesirable substances to adhere to metal surfaces, and methods of neutralizing them are discussed.—R. A. R.

Developments in Shotblasting. R. Ankers. (Manchester Association of Engineers: Foundry Trade Journal, 1948, vol. 84, Feb. 12, pp. 151–154). Equipment and procedures for mechanical propulsion of the abrasives used in shot-blasting are discussed and an outline is given of the principles and methods of shot-peening. A brief account is included of the liquid-honing, or vapour-blast, finishing process, which is based on the application of very fine abrasives mixed with water, or a chemical emulsion, discharged by compressed air against the surface being treated.—J. R.

Some Technical Applications of the Electrolytic Polishing of Metals. R. E. Halut. (Electrodepositors' Technical Society: Sheet Metal Industries, 1948, vol. 25, Jan., pp. 113–121, 124).—R. A. R.

Modern Wire Pickling Practice and Plant Design. E. Mulcahy. (Wire Industry, 1947, vol. 14, May, pp. 269–271; June, pp. 321–322, 330; July, pp. 377–380; Aug., pp. 441–442). The sulphuric and hydrochloric acid methods of pickling wire are compared in Part I of this series of articles. Part II deals with pickling copper rods. Part III describes tanks for pickling and for acid storage, and Part IV gives details of acid recovery systems.—R. A. R.

Metallic Abrasives. J. E. Hurst. (Institute of Vitreous Enamellers: Iron and Steel, 1948, vol. 21, Jan., pp. 18–22). **Methods of Testing Metallic Abrasives.** J. E. Hurst. (Foundry Trade Journal, 1948, vol. 84, Jan. 22, pp. 73–80). Methods are described for the testing and evaluation of metallic shot and grit used in the cleaning or treatment of surfaces by blasting processes.—J. R.

Modern Mechanical Surface Finishing—Conclusion. M. Manler. (Metal Finishing, 1947, vol. 45, Nov., pp. 62–66; Dec., pp. 82–88). The efficiency of polishing wheels, buffs, belts, and buffing compounds is discussed.—R. A. R.

Flame Descaling. Montillot. (Centre de Documentation Sidérurgique, Circulaire d'Informations Techniques, 1947, vol. 4, June 25, No. 8, pp. 27–37). The results of tests carried out with flame descaling at the following French steelworks are outlined: Établissements Marrel; Compagnie des Forges et Aciéries de la Marine et d'Homécourt; Établissements Schnieder et Cie.; Société Anonyme d'Escaut et Meuse; Aciéries Électriques d'Ugine. The experiments carried out at Ugine are described in detail.—J. C. R.

Testing of Alkaline Metal Cleaners. A. Mankowich. (Metal Finishing, 1947, vol. 45, Dec., pp. 77–78). Methods of testing and comparing the efficiencies of alkaline cleaning agents for metals are described.—R. A. R.

PROTECTIVE COATINGS

Introductory Survey of Electroplating R. Mansell. (Metal Finishing, 1947, vol. 45, Nov., pp. 70–74; Dec., pp. 79–81). Electroplating tanks and racks are described, and applications of cadmium, zinc, and chromium coatings are discussed.—R. A. R.

Danger of "Masked Pores" and Methods for Their Determination. A. Glazunov. (Journal of the Electrodepositors' Technical Society, 1948, vol. 23, pp. 9–13). Plating conditions and other factors which may lead to the formation of masked pores in electrodeposited coatings are described, and details of a method of detecting them are given.—R. A. R.

The Determination of the Thickness of the Zinc Layer on Galvanised Iron by Britton's Method. H. A. J. Pieters. (Chemisch Weekblad, 1947, vol. 43, p. 455: Chemical Abstracts 1948, vol. 42, Jan. 10, p. 90).

A Study of Films Isolated from Passive Stainless Steels. E. M. Mahla and N. A. Nielsen. (Journal of the Electrochemical Society, 1948, vol. 93, Jan., pp. 1–16). By using a bromine-methanol solution the authors isolated passive films from electrolytic chromium ferritic and austenitic stainless steel and from the alloys Nichrome V and Inconel. The films were very thin and transparent and were found to be formed on initially film-free (pickled) surfaces by air exposure and by passivation treatments in HNO_3 and in HNO_3-$K_2Cr_2O_7$ solutions. These passive films have been examined by both light microscopy and electron microscopy and by electron diffraction. Chemical analyses indicate that both chromium and iron are major constituents in the films from stainless steels 430 and 317. It is believed that these are present together in solid solution, possibly in a type of crystalline lattice. The films from chromium passivated in HNO_3 have been shown to contain a high percentage of chromium as Cr_2O_3.

Measurement of Thickness of Copper and Nickel Plate—A Comparison of Methods. G. B. Bowman. (Monthly Review of the American Electroplaters' Society, 1947, vol. 34, Oct. pp. 1149–1151). An experimental comparison of the chemical and magnetic methods of measuring the thickness of copper and nickel coatings on steel is reported. For nickel, both methods gave values within $\pm 10\%$ of that estimated with the microscope, which is assumed to be the correct value. The values for copper varied considerably more, especially for thin coatings; this variation may be due to inaccuracy in the microscopic determinations.—C. O.

Drop Test for Determining Thicknesses of Zinc Coatings. R. Springer. (Monthly Review of the American Electroplaters' Society, 1947, vol. 34, Oct., p. 1147). Details are given of a chemical method of determining the thickness of zinc coatings deposited from alkaline solutions containing sulphides. The number of drops of a sulphuric-acid/chromic-acid solution required to expose the base metal is found, and a correlation factor applied.—C. O.

Alloy Additions in Hot Galvanizing Baths. H. Bablik. (Métallurgie, 1947, vol. 79, Dec., pp. 23, 25). Metals, in the form of alloys, are sometimes added to galvanizing baths to obtain the following results: Reduced zinc consumption; reduced brittleness of the zinc coating; and, improvement in the appearance of the zinc coating. The effect of different aluminium additions is discussed in detail, and brief reference is made to the effect of copper, lead, cadmium, and antimony.—J. C. R.

The Presence of Lead in Galvanizing Baths. A. Gordet. (Métallurgie, 1948, vol. 80, Jan., pp. 19, 23; Feb., p. 19). A brief note is presented on the effect of the presence of lead in galvanizing baths.—J. C. R.

Gas-Fired Hot Dip Galvanising Equipment. A. D. Wilcox. (Industrial Gas Times, 1947, vol. 11, Oct., pp. 8, 10, 12, 14). The author deals with three factors which affect the success of the hot-dip galvanizing process, namely: (1) Control of base material, (2) preparation of base material for galvanizing, and (3) design and operation of the spelter kettle.—R. E.

Blue Finishing Steel. L. Sanderson. (Engineering Materials and Processes, 1946, vol. 4, No. 10, pp. 300–302: Metallurgical Abstracts, 1948, vol. 15, Jan., p. 193). Steel (except stainless) is blued by placing in hot charcoal, immersing in a caustic-nitrate solution at 145°–155° C., copper-plating followed by a 5-min. dip in 5% copper acetate, or treatment in a molten 50/50 $NaNO_3$ and KNO_2 mixture containing MnO_2.

The Industrial Enamelling of Metals in the Electric Furnace. R. Malgat. (France Energétique, 1947, Jan.–Feb., pp. 23–33: [Abstract]. Chaleur et Industrie,

1948, vol. 29, Jan., p. 4D). The following subjects are dealt with in this article: Composition and preparation of enamels; tests, acid resistance and mechanical properties of enamels; preparation of surfaces; and electric enamelling furnaces.—J. C. R.

The German Vitreous Enamel Industry. (British Intelligence Objectives Sub-Committee, 1948, Final Report No. 944: H.M. Stationery Office).

Organic Finishes for Metals. H. R. Clauser. (Materials and Methods, 1947, vol. 26, Dec., pp. 96–106). The selection of organic coatings for metals for particular purposes, and the ingredients and preparation of undercoatings and top coatings are discussed.—R. A. R.

Paints Used by the Royal Navy. C. D. Lawrence and G. E. Gale. (Paint Technology, 1947, vol. 12, June, pp. 215–222: [Abstract]. Chimie et Industrie, 1948, vol. 59, Feb., p. 63). The characteristics of and tests on anti-fouling, anti-corrosion, and weather-work paints for the Royal Navy are described.—R. F. F.

Anti-Fouling and Anti-Corrosive Paints Used by the German Navy. (British Intelligence Objectives Sub-Committee, 1948, Miscellaneous Report No. 62: H.M. Stationery Office).

Effectiveness of Anti-fouling Paints. (Peintures, Pigments-Vernis, 1948, vol. 24, Jan., pp. 15–17). The effectiveness of anti-fouling paints is critically discussed and reasons advanced for failures in service.—R. F. F.

Plastic Antifouling Paints for Underwater Use, Applied Hot. H. L. Aldrich. (Paint, Oil and Chemical Review, 1947, vol. 110, Jan., pp. 8, 30–31, 34: [Abstract]. Peintures, Pigments-Vernis, 1948, vol. 24, Jan., p. 27). The manufacture and application of a plastic marine paint is described.—R. F. F.

Contribution to the Study of the Protection of Steel by Tar-Aluminium Paints. P. Peissi. (Office Technique pour l'Utilisation de l'Acier, 1947). Sections of a steel archway were coated with concentrated or dilute tar solutions and afterwards sprayed twice with tar solutions mixed with aluminium powder, at varying distances and varying intervals. The sections were examined after one, four, five, and ten years' exposure and the results of the observations are tabulated. These indicated that the paints have excellent protective properties.—J. C. R.

Cementiferous Paints. J. E. O. Mayne and R. S. Thornhill. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., pp. 219–228).

Elastic Properties of Paint Flms for Metals. S. Conolly. (Metal Treatment, 1947, vol. 14, Winter Issue, pp. 222–226). This article describes experimental work carried out by the author, on the elastic properties of paint films detached from specially prepared metal surfaces. Particular attention is given to the effects of modification of the drying oils, pigmentation and incorporation of resin.—R. A. R.

How to Choose the Correct Type of Porcelain Enamel for Specific Applications. J. E. Hansen. (Steel Processing, 1947, vol. 33, Nov., pp. 688–693).

POWDER METALLURGY

Electrolytic Iron Powder Production. W. J. Granberg. (Iron Age, 1947, vol. 160, Dec. 25, pp. 70–72). An electrolytic process for producing 10 tons/day of iron powder from borings and turnings is described. The scrap is leached with ferric chloride to produce ferrous chloride and the latter is made the electrolyte in cells with graphitic carbon anodes and stainless steel cathodes.—R. A. R.

Evaluation of the Molding, Coining, and Sintering Properties of Iron Powder. J. F. Kuzmick. (American Institute of Mining and Metallurgical Engineers, Technical Publication No. 2308: Metals Technology, 1948, vol. 15, Jan.). Methods of evaluating the moulding, coining, and sintering properties of iron powder are presented, and an example of their application to a Swedish iron powder is given.—R. A. R.

Hard Metal in Industry. G. J. Trapp. (Manchester Association of Engineers, Feb. 20, 1948: Advance Copy). The sequence of operations in the manufacture of hard metal, or cemented carbide, is described in detail. The physical properties and applications of the hard metals are given and discussed.—R. A. R.

Progress in Powder Metallurgy. E. R. Parker. (Mining World, 1947, vol. 9, No. 5, pp. 25–27).

Further Details of German Powder Metallurgy. (British Intelligence Objectives Sub-Committee, 1948, Final Report No. 1569: H.M. Stationery Office). New methods based on practice in the ceramic industry were developed in Germany and applied to the manufacture of high-strength sintered steel parts for automatic weapons. Detailed descriptions of the processes and the pressing tools are given. A 100-ton press for operation with ceramic-type tools, and the rotating-disc method of powder production are described.—R. A. R.

Desulphurization of Iron at about 1100°. H. J. Tress. (Chemistry and Industry, 1948, Jan. 24, p. 57). The removal of sulphur from ferrous sulphide and high-sulphur steel powders is discussed.—J. R.

German Powder Metallurgy. (British Intelligence Objectives Sub-Committee, June, 1947, F.I.A.T. Final Report No. 772: H.M. Stationery Office). German methods of making hard sintered carbides, particularly the hot-press method, are described, and their application for projectile cores and cutting tools discussed. The manufacture of ferrous metal powders and shell rotating bands are also dealt with.—R. A. R.

Two Products of Powder Metallurgy. J. C. Ceccaldi. (Machines et Métaux, 1947, vol. 31, Nov., pp. 375–376). The use of powdered metals for the manufacture of filters and bearings is discussed.—R. F. F.

PROPERTIES AND TESTS

Size in Relation to the Physical and Mechanical Properties of Metals. Winifred Lewis. (Société Française de Métallurgie: Revue de Métallurgie, 1947, vol. 44, Mar.–Apr., pp. 122–123). Investigations on the influence of the size of finished metal products on their physical and mechanical properties, are reviewed.—R. F. F.

Physico-Chemical Properties of Metallic Surfaces Discovered by Electrolytic Polishing. P. Lacombe, P. Morize, and G. Chaudron. (Société Française de Métallurgie: Revue de Métallurgie, 1947, vol. 44, Mar.–Apr., pp. 87–90). Reference is made to the effect of electrolytic polishing on the electric potential of iron.—R. F. F.

Notes on Steels from the Point of View of Their Relationship to Physics. A. Portevin. (Journal de Physique et le Radium, 1943, Series 8, vol. 4, Feb., pp. 17–31). A review is presented of the properties and usual mechanical characteristics of steels, the principal types of steels and their uses; transformations and structures and their applications in experimental physics.—J. C. R.

Influence of Stress-Relieving Annealing on the Structure of the Pearlite and the Mechanical Properties of Cast Steels. F. Meunier. (Société Française de Métallurgie: Revue de Métallurgie, Mémoires, 1947, vol. 44, Jan.–Feb., pp. 39–46). The present paper deals with the effect of the stress-relieving anneal on the structure of the pearlite and the mechanical properties of cast steel, and with the influence of the initial structure of the pearlite. In the carbon steels examined (C 0·16–0·435%) the influence of the anneal on the pearlite,

sometimes considerable, was related to the time and temperature of treatment, the lamellar pearlite passing progressively into the globular form by coalescence of the cementite lamellæ. The coalescence of the cementite could, to a certain extent, negative the improvement due to the stress-relieving anneal; hence, for carbon steels there was no advantage in carrying out the treatment above 600-650° C. The importance of the preliminary normalizing treatment lay in its effect on the initial structure of the pearlite.—A. E. C.

The Dynamic Properties, Endurance Capacity, and the Specification of Steels for Parts of Motors Liable to Fatigue. A. Fotiadi. (Société Française de Métallurgie: Revue de Métallurgie, Mémoires, 1947, vol. 44, Jan.–Feb., pp. 12–38; Mar.–Apr., pp. 97–121). The author endeavoured to find out if there really is a "dynamic elastic limit" below which metal would never become fatigued and above which it would fail sooner or later.

To determine the dynamic elastic limit under rotary bending conditions a cantilever specimen is rotated (at 3000 r.p.m.) under a selected load for 5 min., and the deflection of the free end is measured and noted at the end of each minute. A suitable load increment is added and the procedure repeated, and this is continued as long as may be required. As soon as the stress exceeds the dynamic elastic limit the deflection under a given load no longer remains constant during the period, but increases progressively; if the excess of stress over the limit is increased, the rate of progressive deflection likewise increases. Also, on passing the limit, the temperature of the specimen rises, by an amount depending on the amount by which the stress exceeds the limit. When the rate of progressive deflection reaches about 15–20 mm. $\times 10^{-3}$ the specimen begins to heat-tint.

The dynamic shear elastic limit in torsion can also be determined; the couple applied in an alternating torsional test is increased at 5-min. intervals, but here the temperature of the specimen is measured at one-minute intervals. When the dynamic elastic limit is passed, if the mean of the applied couple is zero, the temperature rises fairly rapidly during the first minute and then more slowly, and the maximum couple applied decreases somewhat, the rate diminishing with time; but if the mean of the couple is not zero, the temperature rises for a few seconds and then returns to normal, while the maximum couple applied diminishes somewhat and then remains steady, and the minimum couple decreases in a few seconds to a steady value less than that at the start of the period.

The relations between the dynamic elastic limit in rotary bending, the structural conditions, and other properties of various alloy steels are considered, and factors affecting the fundamental dynamic properties of metals are discussed in detail.—A. E. C.

Deviations from Hooke's Law. Tentative in View of their Experimental Determination. A. Jaquerod. (Société Française de Métallurgie, Mémoires, 1946, vol. 43, Sept.–Oct., pp. 257–264). Hooke's Law is known to be only an approximation; in torsion the moment, and in flexion the retractive force, tending to restore the body to its original state or position, and also the respective elastic moduli vary with the amplitude of displacement. In the author's new method for determining the deviations from the Law of various materials, a long fine wire is held vertically by two fixtures at its ends such that it may be in the untwisted condition or twists of known amount can be applied. At its mid-point it carries a torsion pendulum bob, of which the period of oscillation for small amplitudes is determined when the wire is untwisted and also twisted to a known degree; from the data obtained the variation of the torsional modulus of elasticity with the deflection can be calculated. For the variation of Young's modulus the same scheme is used, but that part of the wire below the bob is replaced by a spiral spring of the material under test (the upper part is of a material of which the torsional characteristics are known); the experimental procedure is similar, providing figures for the calculation of the variation of E with the degree of torsion applied. The results of tests on piano wire, nickel steel, alloys of the Elinvar type and nickel are presented. It is stressed that the conclusion drawn, being based on dynamic measurements, require confirmation by a static method, because the moduli of elasticity are defined statically.—A. E. C.

The Significance of Mechanical Testing. H. E. Davies. (Metallurgia, 1947, vol. 37, Nov., pp. 19–22; Journal of the Birmingham Metallurgical Society, 1947, vol. 27, Dec., pp. 412–422).

Practical Classification of Steels. E. Skerry. (Engineering Inspection, 1947, vol. 11, Winter Issue, pp. 25–28). The following rapid methods of classifying steel are briefly described: (1) Sparking test; (2) chemical spot test for nickel; (3) magnetic sorting bridge; and (4) Spekker steeloscope.—R. A. R.

A Large Universal Testing Machine. (Overseas Engineer, 1948, vol. 21, Feb., pp. 248–249). **A 150-ton Universal Structure Testing Machine.** (Engineer, 1947, vol. 184, Dec. 26, pp. 594–596). **150-Ton Structure Testing Machine.** (Engineering, 1948, vol. 165, Jan. 23, pp. 79–82). A description is given of a machine designed by W. T. Avery, Ltd., for making tension, compression, and transverse tests of up to 150 tons on fabricated specimens. It can take specimens up to 9 ft. 9 in. long for tension, and up to 15 ft. long for compression.—R. A. R.

Present Day Tendencies in the Construction of Testing Machines for Metals. A. Tenot. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 145–156). Illustrated details are given of a variety of modern testing machines.—J. C. R.

Researches on the Scatter of Results of Mechanical Tests on Cast Irons—Applications to the Study of Mechanical Properties of Grey Cast Irons and the Influence of Inoculation of Pearlitic Cast Irons Melted under Oxidising Conditions. P. Bastien and J. Prache. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 57–76). The authors present the results of numerous shear, impact, bend, and hardness tests on three cast irons and note the variations that occur. Using these results as a basis they studied the connection between the carbon and silicon contents and the mechanical properties. They also noted the influence of inoculants or reducing elements on the microstructure and mechanical properties of cast iron previously melted under oxidizing conditions. Such additions were found to have no perceptible effect on the accuracy of tests normally carried out to determine mechanical properties, and even the graphitic structure was not modified.—J. C. R.

Contribution to the Study of the Influence of Silico-Calcium Additions on the Properties of Grey Cast Irons. G. Delbart, A. Thorel, and R. Buquet. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 77–86). Additions of 2% and upwards of silicocalcium were made to grey cast irons and their influence on mechanical properties was noted. The carbon, sulphur, and phosphorus contents decreased, and, although there was considerable variation in the results, it was found that hardness, tensile, and shear strength varied little despite the increased silicon content, but bend strength decreased. There was a slight increase in magnetic permeability.—J. C. R.

Elasticity. H. Jolivet. (Societé Française de Métallurgie: Revue de Métallurgie, 1946, vol. 43, Nov.–Dec., pp. 318-326). The author discusses generally the significance and interpretation of results of elasticity tests on structural materials, the factors influencing them, and their relationship with other properties.—M. V.

Some Notes on Tensile Testing. F. W. Sowa. (Iron Age, 1948, vol. 161, Jan. 22, pp. 68–69). The mechanics of tensile testing involve several interesting and not too well understood phenomena, two of which, namely the work-hardening of the steel and the effect of rate of loading on test data, prompted the test procedures described in this article. Resulting test data, are presented, together with the author's interpretations. Notch effects are also discussed and are compared with results obtained with un-notched specimens.—J. R.

Notch-Tensile Characteristics of a Partially Austempered, Low Alloy Steel. G. Sachs, L. J. Ebert, and W. F. Brown, jun. (American Institute of Mining and Metallurgical Engineers, Technical Publication No. 2321: Metals Technology, 1948, vol. 15, Feb.). An investigation of a partially austempered, and oil-quenched, 1% chromium steel is described. By varying the time of austempering at 860° F. the percentage of intermediate structures formed was varied. Concentric and eccentric tensile tests on notched bars were used to evaluate the degree of embrittlement. The tensile properties were dependent on the hardness and percentage of the intermediate products.—R. A. R.

The Examination of Sheet Bars for Deep-Drawing Sheets by the Twisting Test. F. Eisenkolb. (Stahl und Eisen, 1948, vol. 68, Jan. 29, pp. 43–46). A description is given of a test for determining whether sheet bars are suitable for making sheets for deep-drawing purposes. Lengths of square section are cut from the bars; these are machined and subjected to a twisting test which reveals heterogeneity and other defects.—R. A. R.

Thermo-Elasticity Gauge and Recorder of Torsional Hysteresis by Photography. Appliances for the Thermomechanical Study of Metals. P. Chevenard. (Journal de Physique et le Radium, 1942, Series 8, vol. 3, June, pp. 105–117). Two appliances which have been devised for the thermomechanical study of metals are described. The thermo-elasticity gauge records the modulus-temperature curve and furnishes data necessary for the calculation of the thermo-elastic coefficient. The hysteresis recorder enables internal friction and similar phenomena to be studied.—J. C. R.

Large-Scale Torsional Fatigue Testing of Marine Shafting. S. F. Dorey. (Institution of Mechanical Engineers, Feb., 1948, Advance Copy). This paper describes the design and construction of a new torsional fatigue testing machine of the resonance type capable of generating a reversed harmonic torque of up to $\pm 3 \times 10^5$ lb.-in. in a stationary test shaft, at a frequency of approximately 2500 vibrations/min.—R. A. R.

Impact Strength and Hardness of Aircraft Alloys Down to −423° F. M. G. Fontana and J. L. Zambrow. (Metal Progress, 1948, vol. 53, Jan., pp. 97–101). Data and results are given of impact and hardness tests made on a variety of metals and alloys at temperatures of from + 20 to −253° C.—J. R.

A Simple Theory of Static and Dynamic Hardness. D. Tabor. (Proceedings of the Royal Society, Series A, 1948, vol. 192, Feb. 4, pp. 247–274). When a hard spherical indenter is pressed into the surface of a softer metal, plastic flow of the metal specimen occurs and an indentation is formed. When the indenter is removed it is found that the permanent indentation is spherical in shape, but that its radius of curvature is greater than that of the indenter. It is generally held that this "shallowing" effect is due to the release of elastic stresses in the material around the indentation. It is clear that if the recovery is truly elastic it should be reversible and that a second application and removal of the indenter under the original load should not change the size or shape of the indentation. Experiments show that this is the case. This means that when the original load is re-applied, the deformation of the indenter and the recovered indentation are elastic and should conform with Hertz's equations for the elastic deformation of spherical surfaces. Measurements show that there is, in fact, close agreement between the observed deformation and that calculated from Hertz's equations. These results have been applied to the case of indentations formed in a metal surface by an impacting indenter. In the third part of the paper a simple theory of hardness is given, based on the theoretical work of Hencky and Ishlinsky.—R. A. R.

An X-Ray and Mechanical Investigation of the Process of Flow in Bending. R. Böklen and R. Glocker. (Metallforschung, 1947, vol. 2, Oct., pp. 304–309). Mechanical and X-ray methods were used to determine the relation between the elasticity and the bending moment at the surfaces of square specimens of a chromium–molybdenum steel. The two curves ceased to coincide as soon as the surface layer began to flow. The distribution of the bending stresses was determined by X-ray measurements on the sides of the specimens, and was in good agreement with the theoretical prediction.—R. A. R.

Corrigenda

The abstracts of American Society for Metals Preprints Nos. 27, 18, 20, and 28, appearing on pp. 396, 405, 408, and 412, respectively, of the March Journal should have been dated 1947 instead of 1948.

Study of Surface Layers by Means of X-Rays. C. Legrand. (Comptes Rendus, 1947, vol. 225, Oct. 27, pp. 731–733). An account is given of an X-ray diffraction method for the examination of surface layers of known thickness from 0·1 microns upwards.—J. C. R.

The Use of X-Rays in Industry. H. P. Rooksby. (Mémoires de la Société Royale Belge des Ingénieurs et des Industriels, 1947, Série B, No. 2, pp. 21–41). A review is given of current British methods for the X-ray examination of materials. In the first part the applications of X-ray radiography are considered, and in the second, methods of analysis by X-ray diffraction are outlined.—J. C. R.

Contribution to the Question: Villard Circuit or Direct Current for Technical X-Ray Installations. H. Verse. (Archiv für Metallkunde, 1947, vol. 1, Oct. pp. 32–36). The alternative types of voltage supply (Villard and D.C.) for X-ray tubes up to 300 kV. peak voltage are compared for tubes of different ratings. A plea is put forward for the development of a D.-C. apparatus of universal application.—M. A. V.

Flow, Fracture and Ductility of Metals. D. J. McAdam, jun., G. W. Geil, and Frances J. Cromwell. (American Institute of Mining and Metallurgical Engineers, Technical Publication No. 2296: Metals Technology, 1948, vol. 15, Jan.). The results of an investigation of the flow of notched and unnotched specimens in tensile tests between the yield point and fracture are presented. The metals tested were copper, Monel, duralumin, magnesium alloy, ingot iron, and low carbon steel. During the

flow of a notched or unnotched specimen in tension the radial stress ratio (transverse-radial-stress/longitudinal-stress) changes continuously because of changes in root radius, notch angle, and notch depth. When this ratio increases either by steps or continuously, during flow, the ductility will be less than if the ratio had been constant at the initial value, but will be greater than if the ratio had been constant at the final value. When the ratio decreases during flow, the ductility will be greater than if it had been constant at the initial value, but will be less than if the ratio had been constant at the final value.—R. A. R.

The Behaviour of the Lattice of Polycrystalline Iron in Tension. W. A. Wood. (Proceedings of the Royal Society, Series A, 1948, vol. 192, Feb. 4, pp. 218–231). The stress-strain characteristics have been investigated for two distinct types of lattice plane in specimens of Swedish iron in tension. Earlier observations are confirmed that the metallic lattice under stress ceases to conform with Hooke's law when external plastic deformation occurs, but the deviation differs in the two cases. The elastic range for the (211) spacing appears to be greater than for the (310) spacing. On removal of stress in excess of the "lattice yield," the two types of spacing show a residual strain of opposite sign to the strain under stress, but the magnitude is different. The residual strain is attributed to the onset of internal stresses as a result of plastic flow, and the difference in strain for the different types of plane to a difference in magnitude of the internal stress for grains of different crystallographic orientation. The internal stresses for both types of plane appear to consist of a longitudinal compression and a transverse compression. These components should be balanced by equivalent regions in tension, but none so far have been found. It may be necessary to conclude that such regions are in a state too disordered for coherent reflexion.

The Flow of Metals under Various Stress Conditions. A. L. Nadai. (Proceedings of the Institution of Mechanical Engineers, 1947, vol. 157, War Emergency Issue No. 28, pp. 121–160). A theoretical treatment of the plastic deformation of metals must frequently take into account strains of an order of 10 to 100 times larger than those which can be sustained elastically. The engineering means for dealing with finite strains of this order are reviewed, and new types of strains that seem to offer possibilities for expressing the stress-strain relations required for developing the theories of the flow of metals under various conditions are introduced.—R. A. R.

Recent Developments in Photo-Elasticity. J. Ward. (Transactions of the Institute of Marine Engineers, 1947, vol. 59, Dec., pp. 223–238). Particulars are given of the use of monochromatic circularly polarized light and the technique for counting interference fringes. The construction of the polariscope for quantitative stress analysis is described.—R. E.

Photo-Elasticity. A. Barat. (Machines et Métaux, 1947, vol. 31, Oct., pp. 333–339, 341). The principles of photo-elasticity are outlined and some examples of applications given. Photo-elastic materials are also briefly surveyed.—R. F. F.

Brittle-Lacquer Stress Analysis. E. Barber. (Engineering Materials and Processes, 1945, vol. 5, No. 17, pp. 59–61; No. 18, pp. 87–89: Metallurgical Abstracts, 1948, vol. 15, Jan., p. 199). The advantages, method of use, sensitivity, and applications of the brittle-lacquer method of stress analysis are discussed. The importance of careful surface preparation, lacquer film thickness, and rigid control of the drying conditions is emphasized. Additional applications include tensile and compression pre-stress determinations and the dynamic testing of moving parts.

Stress Determination. (Automobile Engineer, 1947, vol. 37, Dec., pp. 499–500). The materials and techniques which have been developed in the United States for determining stress by the patterns formed on brittle coatings are described.—R. A. R.

Temperature Transitions in Ductility of Steel. W. P. Roop. (Welding Journal, 1947, vol. 26, Dec., pp. 748-s–752-s). The temperature range of the transition from brittle to ductile fracture of steel was studied statistically using the results of Charpy impact tests on 16-in. beams obtained by G. G. Luther, W. E. Ellis, and C. E. Hartbower (*see* Journ. I. and S.I., 1947, vol. 157, Dec., p. 644).

Mechanical Behavior of High Damping Metals. C. Zener. (Journal of Applied Physics, 1947, vol. 18, Nov., pp. 1022–1025). The relation between the various measures of internal friction is independent of the precise mechanism of the dissipation of energy when the internal friction is small, but not when it is large. In this paper the relation between the two measures most commonly used, logarithmic decrement and tangent of the angle with which strain lags behind stress, is deduced for all levels of internal friction in the important case in which the dissipation of energy is due to a relaxation process having a single time of relaxation. The conditions are further derived under which a specimen of such a metal will not vibrate, but returns periodically to its equilibrium configuration.—R. A. R.

Electrical Wire Strain Gauges. L. Champetier. (Machines et Métaux, 1947, vol. 31, Feb., pp. 39–42; Mar., pp. 111–114). The theory and practice of measuring strain by measuring the variations in electrical resistance of a wire are described. The preparation of test-pieces and the methods of measuring variations in electrical resistance are discussed.—R. F. F.

Progress in the Measurement of Internal Friction of Metals and Alloys Using a Coulomb Micropendulum. C. Boulanger. (Comptes Rendus, 1947, vol. 225, Oct. 13, pp. 624–626). The principal causes of inaccuracies with the Coulomb micropendulum are listed and experiments designed to improve the appliance are outlined.—J. C. R.

Measuring Diameter of Fine Wire. R. W. Carson. (Wire and Wire Products, 1947, vol. 22, Dec., pp. 967–971, 995, 996). Instruments and methods for accurately measuring the diameter of wires less than 0·010 in. are described.—R. A. R.

Torsion Fatigue of Notched Test-Pieces. O. Pushner. (Rozpravy, vol. 2, No. 1, pp. 1–47). [In Czech]. An investigation of the effects of notch angle and radius, dimensions of specimen, and tensile strength on the torsional fatigue limit of steel is described.—R. A. R.

Stress Concentration and Fatigue Failures. O. Föppl. (Engineer, 1948, vol. 185, Jan. 30, pp. 114–115). The theory and practice of compression treatment on the surface of bars and components to prevent fatigue failure are discussed. Calculations are made of the stress and strain produced in the core of a bar by surface compression, and the beneficial effect of the treatment on torsion-bar suspension springs is pointed out.

Stress Concentration and Fatigue Failures. S. Timoshenko. (Proceedings of the Institution of Mechanical Engineers, 1947, vol. 157, War Emergency Issue No. 28, pp. 163–169). Mathematical and experimental methods of determining the stress concentration factor for parts with non-uniform stress distribution are explained with examples. Test data on the increase in hardness and fatigue resistance of axles obtained by cold rolling are presented and discussed.—R. A. R.

The Fatigue of Metals. M. Roš. (Société Française de Métallurgie: Revue de Métallurgie, Mémoires, 1947, vol. 44, May–June, pp. 125–143). The author first discusses the character, mechanism and cause of rupture by fatigue and the influence of the lack of true homogeneity and isotropy in metals and of notches on the fatigue values obtained; he then presents a theory of fatigue to cover the cases of both notched and unnotched specimens. Finally he summarizes the most important factors influencing the fatigue of metals.—A. E. C.

The Fatigue Test Using an Increasing Load. M. Prot. (Comptes Rendus, 1947, vol. 225, Oct. 20, p. 669). A brief note is presented on fatigue-testing with a steadily increasing load. The stress at which rupture occurs is more rapidly and accurately determined than when a constant load is used.—J. C. R.

Fatigue Testing Production Parts. C. B. Griffin. (Iron Age, 1948, vol. 161, Jan. 8, pp. 59–62). A fatigue-testing machine that is said to meet most of the conditions of an ideal machine for fatigue-testing full-size parts and assemblies is described in this article, both from the standpoint of construction and of method of operation.—R. A. R.

Influence of Strain Aging on the Fracture Stress of Low-Carbon Steel. D. J. McAdam, jun., G. W. Geil, D. H. Woodward, and W. D. Jenkins. (American Institute of Mining and Metallurgical Engineers: Technical Publication No. 2318: Metals Technology, 1948, vol. 15, Jan.). The present investigation extends that on factors affecting the breaking stress of ferritic steels by McAdam, Geil, and Mebs (*see* Journ. I. and S.I., 1947, vol. 157, Dec., p. 643). The results confirm the conclusion previously arrived at, namely, that the variation of the fracture stress with plastic extension may be represented by a curve above the flow-stress curve; both curves rise at a decreasing rate and intersect at a small angle at the point representing actual fracture.—R. A. R.

Review of Recrystallization Phenomena with the Aid of a New Hypothesis. C. Petersen. (Metallforschung, 1947, vol. 2, Oct., pp. 289–304). It is assumed as a working hypothesis that the growth of nuclei is caused by the elastic energy of a condition of isotropic internal stress within the nucleus. This local elastic space-distortion is due to the differences in plasticity of the crystals and especially of polycrystalline aggregates. This hypothesis supplies a satisfactory explanation of most recrystallization phenomena and is in conformity with the test data in the literature.—R. A. R.

The Notch Effect on the Cold Brittleness of Steel. E. M. Shevandin. (Journal of Technical Physics (U.S.S.R.) 1947, vol. 17, Sept., p. 1011: Journal of the British Shipbuilding Research Association, 1948, vol. 3, Jan., p. 24). The experiments described were undertaken to investigate the influence of the shape of notches on the yield point and brittle strength of mild steel under bending stresses at low temperature. In order to facilitate the direct measurement of stresses and temperature, only static bending tests were made. Low carbon steel (C 0·25%) was overheated for 2 hr. at a temperature of 1200° C. to form a coarse-grained structure with increased brittleness. The yield point was determined for temperatures of + 20° C., − 80° C., and − 140° C. For a specimen having a notch radius of 5 mm., detailed measurements of temperature and yield-point variation were made, and the curve showing their relationship is given. The brittle strength of all the specimens was measured at the temperature of liquid air. It was found that, for notched specimens, the rate of increase of the yield point with decreasing temperature was higher than for specimens without notches. Tests with specimens having notches 5 mm. deep and radii varying from 5 mm. to 0·5 mm. showed that the rate of increase of the yield point with decreasing temperature was not affected by notch shape. The author is unable to explain this result, which is contrary to the well-established facts regarding notch effect in tension. Similarly, the experiments failed to establish the variation of brittle strength in relation to the shape of notches. The author discusses this point in some detail, with particular reference to the effect of temperature on the transition from the ductile to the brittle state in steel.

Cold-Brittleness of Steel in Torsion. F. F. Vitman, N. N. Davidenkov, and N. A. Zlatin. (Iron and Steel Institute, 1948, Translation Series, No. 335). This is an English translation of a paper which appeared in Journal of Experimental and Theoretical Physics. U.S.S.R., 1940, vol. 10, No. 9–10, pp. 1137–1145. The author, using an impact-torsion testing machine of special design shows that a change from uni-axial tension to pure shear involves an appreciable lowering of the critical cold-brittleness temperature owing to a change in the ratio of the normal and shear stresses.—R. A. R.

Brittle Fracture in Mild Steel Plates. J. F. Baker. (Engineering, 1947, vol. 164, Dec. 5, pp. 532–534). *See* Journ. I and S.I., 1947, vol. 157, Oct., p. 300.—R. A. R.

Causes of Low Ductility in Mild Steel. J. F. Baker. (Engineering, 1947, vol. 164, Dec. 5, pp. 548–550). This paper forms an appendix to the author's paper "Brittle Fracture in Mild Steel Plates" (*see* preceding abstract).

Fracture may occur in mild steel without previous measurable plastic deformation. The conditions which have been found by previous investigations to lead to premature failure, particularly those likely to affect welded steel structures, are briefly discussed.—R. A. R.

Brittle Fracture in Mild Steel Plates—Brittleness in Ship Steel. J. L. Adam. (Engineering, 1947, vol. 164, Dec. 12, pp. 556–557). *See* Journ. I. and S.I., 1947, vol. 157, Oct., p. 300.—R. A. R.

Brittle Fracture in Mild Steel Plates. E. Orowan. (Engineering, 1947, vol. 164, Dec. 19, pp. 581–583; Dec. 26, pp. 605–606). *See* Journ. I. and S.I., 1947, vol. 157, Oct., p. 301.—R. A. R.

Brittle Fractures in Mild Steel Plates—Fracture of Metals: Some Theoretical Considerations. N. F. Mott. (Engineering, 1948, vol. 165, Jan. 2, pp. 16–18). *See* Journ I. and S.I., 1947, vol. 157, Oct., p. 301.—R. A. R.

Brittle Fracture in Mild-Steel Plates—Fundamental Aspects of Brittle Steel. D. E. J. Offord. (Engineering, 1948, vol. 165, Jan. 16, p. 53). *See* Journ. I. and S.I., 1947, vol. 157, Oct., p. 301).—R. A. R.

Brittle Fracture in Mild Steel Plates—An American Point of View. E. M. MacCutcheon. (Engineering, 1948, vol. 165, Jan. 23, pp. 77–78). *See* Journ. I. and S.I., 1947, vol. 157, Oct., p. 301.—R. A. R.

Wear of Surfaces by Abrasion. V. C. Shedrow. (Journal of Technical Physics (U.S.S.R.), 1947, vol. 17, Sept., p. 1019). The mathematical formula for abrasive surface wear, established by the author, is in good agreement with the experimental results obtained by N. P. Voinow.

Superfinishing and Examination of Condition of Surfaces. G. Rivière. (Machines et Métaux, 1947, vol. 31, Sept., pp. 297–299). The properties of superfinished surfaces are discussed and apparatus for checking the quality of superfinishes surveyed. Superfinishing methods and the principles of the Foster superfinisher are also described.

The Study of Surfaces with the Electron Microscope. M. Déribéré. (Machines et Métaux, 1947, vol. 31, Apr., pp. 125–128). The electron microscope and its applications to metallurgy are described.—R. F. F.

Time-Dependent Phenomena in Iron-Bearing Materials under the Influence of Mechanical and Magnetic Forces. J. L. Snoek. (Physikalische Gesellschaft: Laboratoria. N. V. Philips' Gloeilampenfabrieken, 1947, Reprint No. 1724). *See* Journ. I. and S.I., 1947, vol. 156, Aug., p. 586.

Paramagnetism of Ferromagnetic Elements. M. Fallot. (Journal de Physique et le Radium, 1944, Series 8, vol. 5, Aug., pp. 153–163). Results are presented of a study of the magnetic susceptibility of nickel, iron, cobalt, iron–nickel, and iron–aluminium alloys up to 1500° C.—J. C. R.

Study of the Permeability of a Ferro-Nickel under Tension. M. Bayen. (Journal de Physique et le Radium, 1944, Series 8, vol. 5, Apr., pp. 57–62). The author has studied hysteresis phenomena using a ferronickel wire (Fe 43–43·2%, Ni 55·5–56·2%) and has paid special attention to the part played by the demagnetizing field.—J. C. R.

The Thermal Variation of the Hysteresis Cycle of Some Ferromagnetic Materials. I—Phenomena in the Neighbourhood of the Curie Point. R. Forrer and R. Baffie. (Journal de Physique et le Radium, 1944, Series 8, vol. 5, June, pp. 97–108).

The Thermal Variation of the Hysteresis Cycle of Some Ferromagnetic Materials. II—Remanence, Coercivity, and Structural Field of Cobalt. R. Forrer, R. Baffie, and P. Fournier. (Journal de Physique et le Radium, 1945, Series 8, vol. 6, Feb., pp. 50–56).

The Thermal Variation of the Hysteresis Cycle of Some Ferromagnetic Materials. III—Some Ferromagnetic Combinations. Relationship between Thermal Anomalies and Crystal Structure. R. Forrer, R. Baffie, and P. Fournier. (Journal de Physique et le Radium, 1945, Series 8, vol. 6, Mar., pp. 71–87).—J. C. R.

The Laws of Magnetization and of the Subdivision in Elementary Fields of a Single Crystal of Iron. L. Néel. (Journal de Physique et le Radium, 1944, Series 8, vol. 5, Nov., pp. 241–251; Dec., pp. 265–276).—J. C. R.

The Measurement of the Magnetic Properties of Fine Wires. P. T. Hobson, E. S. Chatt, and W. P. Osmond. (Electronic Engineering, 1947, vol. 19, Dec., pp. 383–388: [Abstract]. Bulletin of the British Scientific Instrument Research Association, 1948, vol. 3, Jan., pp. 15–16). The apparatus described measures the remanence and coercivity of fine wires of 0·0014-in. diameter with a maximum applied field of 1000 oersteds, and with a maximum sensitivity to allow readings of remanence as low as 100 gauss to be made. An appendix is given on the application of differential permeability curves in the magnetic analysis of alloys.

Sorting Metals Magnetically. H. Sanders. (Engineering Materials and Processes, 1946, vol. 4, No. 12, pp. 358–360: Metallurgical Abstracts, 1948, vol. 15, Jan., p. 199). Details and diagrams of the detector circuit of a magnetic comparator are given.

Investigation of the Eddy-Current Anomaly in Electrical Sheet Steels. F. Brailsford. (Journal of the Institution of Electrical Engineers, 1948, vol. 95, Part II, Feb., pp. 38–48). The well-known discrepancy between the calculated value of the eddy-current losses in electrical sheet steels at supply frequencies and the experimentally observed value is discussed. The effect of the flux wave-form distortion due to magnetic non-uniformity of laminations is examined experimentally and found to be small. It is shown, however, from experiments on a model, that inside each lamination the flux wave-form distortion with alternating magnetization is severe, and is sufficient to cause the hysteresis loss per cycle to be strongly frequency-dependent. On the other hand, the discrepancy which occurs with alternating magnetization is found to be absent with a pure rotational flux where there are no wave-form effects. It is concluded that, without having recourse to more elaborate explanations, the observed anomaly might be largely accounted for by the increased hysteresis loss brought about by internal flux wave-form distortion, the true eddy-current loss being, in fact, not appreciably different from its calculated value.

Design of an Ultrasonic Analyzer. (Electronics, 1947, vol. 20, Dec., pp. 102–105). Particulars are given of equipment for the non-destructive inspection of metal strip and the testing of uniform parts; it comprises a noise generator, transmitter, piezo-electric transducers, and a recording receiver. With this equipment the location of a flaw can be automatically marked on the part.

Ultrasonic Tests. C. H. Desch. (Société Française de Métallurgie, Autumn Meeting, Oct. 22, 1946: Revue de Métallurgie, Mémoires, 1946, vol. 43, Sept.–Oct., pp. 253–256). The author gives an account of the development of the ultrasonic method of detecting internal defects in materials (such as cracks in steels) described by himself, Sproule, and Dawson (*see* Journ. I. and S.I., 1946, No. I, p. 319P). indicating some of the research uses to which it has been put, and briefly describes other methods of testing in which ultrasonics are used. He mentions that the bat " sees " in the dark by emitting ultrasonic squeaks, the reflections of which it receives with its large ears, thus locating surrounding objects.—A. E. C.

Vector Fields to Locate Deep-Seated Defects in Steel. R. M. Killen. (Materials and Methods, 1947, vol. 26, Dec., pp. 66–67). A magnetic-powder technique for detecting defects well below the surface of thick steel plate is described. The novel feature is that a vector field is created in the plate by superimposing an A.C. field on a stronger D.C. field.—R. A. R.

Thermal Expansion Properties of Iron-Cobalt Alloys. M. E. Fine and W. C. Ellis. (American Institute of Mining and Metallurgical Engineers, Technical Publication No. 2320: Metals Technology, 1948, vol. 15, Feb.) The paper reports the expansion properties of iron–cobalt alloys in the 30°–850° C. temperature range; these are correlated with other physical properties and an explanation is proposed for the interrelation.—R. A. R.

How Low Temperature Treatments Affect Properties of Steel. H. W. Gillett. (Product Engineering, 1947, vol. 18, Dec., pp. 81–84). The temperature range of martensite formation is discussed with special reference to the effects of cooling down to −75° F., and of subsequent tempering.—R. A. R.

The Strange Behaviour of Metals at Very Low Temperatures. D. H. Andrews. (Refrigerating Engineering, 1947, vol. 54, Nov., pp. 482–483).

Selection of High Temperature Materials for Gas Turbines. Rebecca H. Smith. (Iron Age, 1948, vol. 161, Jan. 22, pp. 56–60). A critical review of the factors governing the selection of materials for gas-turbine components is presented. Oxidation and corrosion resistance, load-carrying ability, structural stability, and fatigue strength and ductility at elevated temperatures are among the general requirements discussed and evaluated. The problems encountered in selecting the best material for a component in the gas turbine are also considered from the metallurgical as well as the economic standpoint, embracing the use of castings, forgings, and bar stock.

The Problem of High Temperature Alloys for Gas Turbines. Sir William T. Griffiths. (Journal of the Royal Aeronautical Society, 1948, vol. 52, Jan., pp. 1–26). The metallurgical requirements of gas-turbine components and their fabrication are outlined and the lines of development in various countries since 1939 are discussed.

Spheroidization of Molybdenum Steel in High Temperature Service. R. F. Miller, E. V. Golaszewski, and G. V. Smith. (Metal Progress, 1948, vol. 53, Jan., pp. 79–82). Changes in microstructure and hardness in normalized specimens of a 0·14% carbon, 0·53% molybdenum fine-grain-deoxidized steel exposed for various periods to temperatures of from 1000° to 1300° F. are discussed and illustrated. Spheroidization, but no graphitization, of the specimens was observed.—J. R.

German Special Steels for Gas Turbines. R. Scherer. (Centre de Documentation Sidérurgique, Circulaire d'Informations Techniques, 1947, vol. 4, June 25, No. 8. pp. 5–22). The author considers the requirements of three kinds of steels: those possessing good mechanical properties up to 550° C. used for shafts and rotor discs; those resistant to oxidation at high temperatures but not required to possess good mechanical properties at these temperatures, used for the turbine housing; and heat-resisting steels possessing good mechanical properties at temperatures above 550° C., used for turbine blades. The analyses and mechanical properties of German special steels used for these purposes are given, with particular reference to their resistance to creep.—J. C. R.

Creep Testing. (Automobile Engineer, 1947, vol. 37, Dec., p. 498). A new creep-testing machine developed by the Baldwin Locomotive Works is described. Of lever-arm design, it has a maximum capacity of 12,000 lb. Testing temperatures up to 2200° F. can be obtained, while strain can be measured to 0·000025 in.—J. P. S.

Influence of Preliminary Annealing of Iron in Hydrogen on Its Subsequent Behaviour when Impregnated Cold with this Gas. P. Bastien. (Comptes Rendus, 1947, vol. 225, Dec. 22, pp. 1321–1322). Six samples of Armco iron wire were tested; two were annealed in argon, and the remainder in hydrogen at 880° C. for 48 hr. They were then impregnated with hydrogen at 15° C., either by electrolysis or by acid attack; immersed in mercury for 1000 hr. at 15° C. and finally kept at 15° C. for 1000 hr. and at 60° C. for 500 hr. The brittleness was measured by bend tests at each stage in the treatment, and the volume of hydrogen evolved was determined. Samples annealed in argon showed marked embrittlement after cold impregnation, especially by electrolysis, followed by complete recovery at 60° C. Samples annealed in hydrogen could be divided into two groups. The first group had a fine structure; there was hardly any embrittlement after cold impregnation by acid attack, and only moderate embrittlement after electrolytic attack. The second group had a coarse irregular structure, with intergranular fissures. These samples were very brittle after the preliminary anneal, and throughout the subsequent treatments.—M. A. V.

Monocrystalline Iron Does Not Acquire Brittleness on Pickling. G. Chaudron. (Métaux, Corrosion, Usure, 1942, vol. 17, Apr., pp. 51–53). The absorption of hydrogen into steel electrolytically and by pickling is discussed, and details are given of experiments on single crystals of Armco iron and electrolytic iron the hardness of which was measured initially and after alternate 12-hr. periods in hydrochloric acid and in boiling water. Whereas polycrystalline iron tended to become softer after being in the acid and to regain some of its initial hardness while in the boiling water, the monocrystalline irons showed a slight increase in hardness without modification after being in boiling water. Bend tests were also carried out and the results showed that the single crystals exhibited no hydrogen embrittlement.—J. C. R.

The Two Modes of Hydrogen Evolution During Annealing of Iron. A. Portevin, G. Chaudron, and L. Moreau. (Métaux, Corrosion, Usure, 1942, vol. 17, Oct., pp. 175–177). Polycrystalline and monocrystalline iron specimens which had been artificially impregnated with hydrogen by electrolysis were heated in a vacuum to different temperatures and the retained gas was measured by the Chaudron-Moreau ionic-bombardment method. Micrographic examinations, and hardness and brittleness tests were also carried out. Hardness and brittleness decreased with increase in temperature and length of annealing time. Less hydrogen was evolved at 300° than at 600° C. and it is concluded that in the former case a considerable proportion of gas was released from the lattice and remained included in the grain boundaries. Polycrystalline specimens heated to 250–300° C. contained in the lattice only one third of the initially absorbed hydrogen, but it redissolved in the lattice on heating to 900° C. Monocrystalline iron heated to 300° C. retained nearly all the initially absorbed hydrogen in the lattice. —J. C. R.

Effect of Cold Work Hardening on the Oxidation of Iron. J. Bénard and Odile Coquelle. (Société Française de Métallurgie: Revue de Métallurgie, 1947, vol. 44, Mar.–Apr., pp. 82–86). The effect of abrasion, cold rolling and tension on the oxidation of iron was studied. Small Armco iron plates 2 mm. thick with 1·5 sq. cm. surface, used for the abrasion and rolling tests, were obtained by rolling 12-mm. round bars and annealing at 900° C. in a jet of pure dry hydrogen. For the abrasion test emery papers Nos. 4, 0, and 0000 were used and the samples washed with ether and alcohol. For the rolling test, the samples were reduced by 27%, 50%, and 74% and polished electrolytically. Immediately after treatment they were subjected to oxidation at 850° C. for 15 min., 1 hr., 3 hr., and 6 hr. The amount of oxygen absorbed by the samples, corresponding to the increase in weight of the sample, was measured with a microbalance. For the tensile tests similar plates were prepared by subjecting them to tensile stress almost to fracture. These were subjected to oxidation tests after anodic polishing. The results showed that the rate of oxidation of iron, in a dry atmosphere at 850° C., is influenced by cold work hardening and is dependent on the structure of the metal. The abrasion tests showed that the rate of oxidation varied in inverse ratio to the coarseness of the abrasive. With rolling, the rate of oxidation increased with reduction. In the tensile test, the oxidation rate increased at the beginning, with increasing load, but decreased when fracture approached.—R. F. F.

The Effect of Very Small Quantities of Sulphur and of Oxygen Inclusions on the Quality of Steels. L. Colombier. (Société Française de Métallurgie; Revue de Métallurgie, 1947, vol. 44, Jan.–Feb., pp. 47–57). The influence of small quantities of sulphur in steel, as shown by changes in elasticity, was studied. Tests were carried out on two steels to which sulphur was added. The compositions were: (1) C 0·19%, Si 0·29%, Mn 0·41%, Ni 4·58%, Cr 1·29%, Mo 0·52%, P 0·013%, S (before addition) 0·007% (after addition) 0·012%; (2) C 0·37%, S 0·29%, Mn 0·36%, Ni 2·60%, Cr 0·70%, P 0·015% and S (before addition) 0·007%, (after addition) 0·014%. The results of elasticity tests on specimens before and after the addition of sulphur, and after annealing at 546°, 570°, 595°, and 615° C. for steel (1) and at 500°, 550°, 600°, and 650° C. for steel (2) are tabulated. Bars of steels of compositions similar to (1) were examined micrographically and divided into three groups according to the type of predominating oxide inclusions, *viz.*. Group I: Globular silica inclusions, dispersed throughout the mass of the metal, which are rarely greater than 0·01 mm. in dia. Group II: Non-plastic alumina or aluminates which are of irregular shape and rarely larger than a few microns; they are dispersed throughout

the mass of the metal, but often in streaks several millimetres long. Group III : Plastic inclusions, lengthened by forging, of different types such as silicate or silico-aluminates of iron, manganese, or calcium. Longitudinal and transverse elasticity tests on samples in each group were made in order to compare the influence of each type of inclusion.—R. F. F.

Chromium–Nickel Stainless Steels. J. Galibourg. (Centre d'Information du Nickel, 1947, No. 6 : [Abstract]. Aperçu de la Presse Technique, 1948, vol. 3, Jan., p. 1). The composition, physical and mechanical properties, corrodibility, heat-treatment, mechanical treatment, welding, and casting of chromium–nickel stainless steels are reviewed.—J. C. R.

Chromium–Nickel Steel for Machine Parts. J. Galibourg. (Centre d'Information du Nickel, 1947, No. 7 : [Abstract]. Aperçu de la Presse Technique, 1948, vol. 3, Jan., p. 1). The causes of deformation, rupture, and wear of machine parts are reviewed.—J. C. R.

Air-Hardened Chromium–Nickel Steel. J. Galibourg. (Centre d'Information du Nickel, 1947, No. 1 : [Abstract]. Aperçu de la Presse Technique, 1948, vol. 3, Jan., p. 1). The properties, heat-treatment, and applications of self-hardening chromium–nickel steels are reviewed. —J. C. R.

Semi-Hardened Chromium–Nickel Steel. J. Galibourg. (Centre d'Information du Nickel, 1947, No. 2 : [Abstract]. Aperçu de la Presse Technique, 1948, vol. 3, Jan., p. 1). The properties, heat-treatment, and applications of semi-hardened chromium–nickel steels are reviewed.—J. C. R.

Mild Chromium–Nickel Steel. J. Galibourg. (Centre d'Information du Nickel, 1947, No. 3 : [Abstract]. Aperçu de la Presse Technique, 1948, vol. 3, Jan., p. 1). The properties, forging, heat-treatment, and applications of mild chromium–nickel steels are reviewed.—J. C. R.

Case-Hardened Steel Containing 2% to 6% of Nickel. J. Galibourg. (Centre d'Information du Nickel, 1947, No. 4 : [Abstract]. Aperçu de la Presse Technique, 1948, vol. 3, Jan., p. 1). Chemical compositions, heat-treatments mechanical properties, and applications of case-hardened steels containing 2% to 6% of nickel are reviewed.—J. C. R.

Cast Nickel Steels. J. Galibourg. (Centre d'Information du Nickel, 1947, No. 5 : [Abstract]. Aperçu de la Presse Technique, 1948, vol. 3, Jan., p. 1). The properties, heat-treatment, and applications of cast nickel steels are reviewed.—J. C. R.

Some Properties of Silicon and Titanium Stainless Steels. (British Intelligence Objectives Sub-Committee, 1948. F.I.A.T. Technical Bulletin T-29 : H.M. Stationery Office). The results of tests at the Krupp Works, Essen, on high-alloy chromium–nickel steels with additions of titanium, silicon, and molybdenum are given ; both magnetic and corrosion-resistant properties are included. It was impossible to hot-roll the silicon steel if it had been melted in a high-frequency furnace, but the same type of steel produced in an arc furnace or low-frequency furnace could be rolled without difficulty.—R. A. R.

Bibliography of Chromium–Nickel Austenitic Stainless Steels. (International Nickel Co. Inc., New York). This bibliography consists of references to selected published data on the mechanical and physical properties of chromium–nickel stainless steels and covers the period from Jan. 1, 1935 to Dec. 31, 1945. The scope of the bibliography is limited to those articles which present data on the properties of iron-base alloys containing from 12% to 30% of chromium and 6% to 30% of nickel with or without alloying additions. The corrosion properties of these alloys have been omitted.—R. E.

Stainless and Heat-Resisting Steels. (Mechanical World, 1948, vol. 123, Feb. 6, pp. 153–155). The physical properties of ferritic and austenitic stainless steels are discussed.—R. A. R.

Developments in High Speed Steels. J. Jacquet. (Pratique des Industries Mécaniques, 1947 July, pp. 218–220: [Abstract]. Aperçu de la Presse Technique, 1948, vol. 3, Jan., p. 1). An account is given of experiments carried out in the United States on high-speed steels containing molybdenum and having a lower tungsten content than usual. These steels are less brittle and have a greater torsional strength.—J. C. R.

Heat-Resistant Alloys. A. Martigny. (Métallurgie, 1947, vol. 79, Nov., pp. 13–15). An account is given of present-day heat-resisting steels and their mechanical properties, with particular reference to creep.—J. C. R.

How to Develop Maximum Strength in Alloy Steel Bolts. G. Sachs. (American Institute of Bolt, Nut and Rivet Manufacturers : Steel, 1948, vol. 122, Feb. 2, pp. 104–106). Tests were carried out on 3·5% nickel steel bolts $\frac{3}{8}$-in. in dia. to study factors causing embrittlement. In tension, with little or no superimposed bending, ductile fractures occur except in the as-quenched bolts. Brittle fractures occurred under the head at low and widely scattered loads, thus indicating greater notch-sensitivity at this point than in the threads.—R. A. R.

New Die Steel for the Die Casting Industry. W. G. Johnson. (Die Casting, 1947, vol. 10, Oct., pp. 26, 28, 30). Reference is made to an alloy die steel, known as PH2, which is of the precipitation-hardening type. No particulars are given of its composition.—R. E.

A Clinical Approach to Weldment Design. G. von Stroh. (American Society of Mechanical Engineers : Steel, 1948, vol.122, Jan. 19, pp. 68–72, 106). A detailed and critical study is made of the behaviour of welded structures, and in particular failures of such structures, during and after their service life.—J. R.

Improved Metals Promise Design Progress. (Machine Design, 1948, vol. 20, Jan., pp. 103–107). The properties of recently developed low-alloy high-strength steels, heat-resisting tungsten–cobalt–molybdenum steels, nickel alloys, and cobalt alloys are reviewed.—R. A. R.

Notes on the Wartime Inspection of over Two Million Hardened and Tempered Medium and Large Coil Springs for Gun Mountings. H. McLoughlin. (Engineering Inspection, 1947, vol. 11, Winter Issue, pp. 31–33).

When and How to Use Cast Iron. T. E. Eagan. (American Society of Tool Engineers and American Foundrymen's Association : Materials and Methods, 1947, vol. 26, Dec., pp. 71–75). Data are presented on the physical properties, machinability, and heat-treatment of cast iron, and applications in which these characteristics are exploited are discussed.—R. A. R.

Progress in Quality Castings for Machine Tools. G. Martel. (Machines et Métaux, 1947, vol. 31, Aug., pp. 269–273). Cast iron of low carbon contents containing 1% to 2% of nickel has proved suitable for machine-tools, when primary ferrite has been eliminated by the addition of silicon as, if the iron is in the ferritic phase, parts subjected to friction will wear easily.—R. F. F.

Machine Design's Materials Work Sheet. Standard Steels Wrought AISI Types. Part I. (Machine Design, 1947, vol. 19, Sept., pp. 157–167, Nov., pp. 151–163). A comprehensive survey is made of the mechanical and physical properties of the A.I.S.I. types of wrought steels, as they affect engineering design.—C. O.

Selecting Alloy Structural Steels for High-Toughness Applications. B. S. Lement. (Iron Age, 1947, vol. 160, Dec. 25, pp. 80–84). A routine procedure is described for the selection of alloy steel bars from S.A.E. or N.E. specifications for applications requiring a given yield point in the 80,000–150,000 lb./sq. in. range and a diameter up to 5 in.—R. A. R.

Difference in Composition between the Middle and the Surface of Rimming Steel Locomotive Boiler Plates. P. Joumat. (Revue Générale des Chemins de Fer, 1946, Nov., pp. 195–198 : [Abstract]. Centre de Documentation Sidérurgique, Supplément à la Circulaire d'Informations Techniques, 1947, vol. 2, Apr. 15, No. 1, pp. 11–13). The author gives an account of variations in the structure of rimming steel locomotive boiler plates and fire boxes, which occur after a period of service, and concludes that rimming steel is unsuitable for these purposes. —J. C. R.

Recent French Work on Interrupted Quenching. G. Delbart. (Metal Treatment, 1947, vol. 52, Winter Issue, pp. 202–212). This is a review of recent French literature explaining the phenomena of isothermal transformation as a function of time, dealing with the characteristics of the intermediate structures formed in the steel, and considering practical applications for interrupted quenching.—R. A. R.

X-Ray Thickness Control Expected to Step Up Sheet Output. W. N. Lundahl. (Steel, 1948, vol. 122, Feb. 2, pp. 101–102, 117, 118). A description is given of an X-ray device which enables constant and accurate control to be maintained of the thickness of wide strip as it passes at high speed from the finishing mill. There are two X-ray sources from which radiation is directed on to a single pick-up instrument. One source is below the strip being gauged and the other source is placed above a standard sample of the correct thickness. The pick-up compares the intensities of the two X-ray beams and any disparity is registered on an indicating instrument. Gauge deviations above a certain amount can be made to operate a throw-out mechanism. —R. A. R.

METALLOGRAPHY

Tracers in Metallurgy. J. J. Harwood. (Nucleonics, 1948, vol. 2, Jan., pp. 57–61). Radio-active tracer techniques have been applied to the study of diffusion processes in metals in solid and liquid states with a view to extending present knowledge of physical metallurgy and the physical chemistry of steelmaking. A brief report on the research in progress and planned at two American universities is presented.—R. A. R.

Micro-Examination and Electrode-Potential Measurements of Temper-Brittle Steels. D. McLean and L. Northcott. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., pp. 169–177).

The Study of Segregations and Inclusions in Steel by Micro-Radiography. W. Betteridge and R. S. Sharpe. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., pp. 185–191).

The Applications of Electron Diffraction and of Thermomagnetic Analysis to the Study of Films which Form on the Surface of Ferrous Metals. G. Chaudron. (Métaux, Corrosion, Usure, 1942, vol. 17, Mar., pp. 37–41 ; June, pp. 89–93 ; Sept., pp. 155–159). The formation and constitution of oxide films on ferrous metals were studied, using the electron-diffraction method for thin films and thermomagnetic analysis for thicker films. Both methods and the appliances used are described. —J. C. R.

Black Malleable Cast Iron and Rapid Graphitization. M. Guédras. (Métallurgie, 1947, vol. 79, Nov., pp. 23–24). A review is presented of the work of various investigators on the graphitization of white cast iron and the decomposition of cementite.—J. C. R.

Test for the Determination of the Average Size of Cementite Particles Contained in the Various Constituents of an Ordinary Steel. P. Bortaud. (Comptes Rendus, 1947, vol. 225, Nov. 10, pp. 875–876). An X-ray method for the examination of the constituents, particularly troostite and sorbite, of a 0·8–1% carbon steel is described. Cementite was found to exist as large crystals only in slowly formed constituents such as globular pearlite.—J. C. R.

Study of Fractures of Iron-Chromium Alloys. C. A. Zapffe. (Société Française de Métallurgie : Revue de Métallurgie, 1947, vol. 44, Mar.–Apr., pp. 91–96). The structures obtained after fracture of samples of seven iron-chromium alloys (Cr 7·7% to 28·67%) was compared with that of a pure electrolytic iron. The samples weighed 2 kg. and were prepared by mixing pure electrolytic iron with commercial ferrochromium of low carbon content. The samples were examined after annealing at 875° C. for 40 hr.—R. F. F.

The Structure of the Eutectic in Grey Cast Iron. A. Portevin and H. Laplanche. (Revue de Métallurgie, Mémoires, 1946, vol. 43, May–June, pp. 129–131). According to the system, stable or metastable, in which they cool, commercial cast irons can be classed as grey irons, giving graphite on freezing without sensible undercooling, and white irons, giving iron carbide on freezing with considerable undercooling. Intermediately, the solidification may be graphitic with medium undercooling and the product is a eutectic mixture of vermiculated fine graphite and ferrite or sometimes pearlite. The normal graphitic eutectic of grey irons is illustrated and discussed in this article. To trace the formation and development of the structures samples of extremely pure hypo-eutectic irons were melted under dry nitrogen, and water-quenched at closely defined temperatures while they were freezing very slowly in the stable system; the residual molten metal froze in the metastable system, producing quenched white iron as the background on which the dendrites of the primary solidification could be clearly seen. The results obtained are illustrated in a series of micrographs. The change of the structure back to the normal for industrial irons as the content of elements such as phosphorus and sulphur rises to figures normal for industrial irons is briefly touched on.—A. E. C.

Determination of Oxide Inclusions in Steel. H. Henkel. (Zeitschrift für Analytische Chemie, 1947, vol. 128, pp. 26–41 : Chemical Abstracts, 1948, vol. 42, Jan. 20, 484). Among the eight proposed ways of studying oxide inclusions in hardened steel, the electrolytic method has proved to be most advantageous. A prismatic sample of the steel is used as anode in a neutral electrolyte. The metals are oxidized by the current and go into solution, while SiO_2, Al_2O_3, FeO, MnO, carbides, sulphides, nitrides, metallic copper, etc., remain and can be determined. Then treatment of the residue with 10% $CuBr_2$ solution serves to remove carbides, sulphides, and nitrides. After this, treatment of the second residue with glycine serves to remove free MnO and does not attack FeS and MnS. The separated oxides can be determined with the photometer; SiO_2 by the silicomolybdate reaction, FeO with thiocyanate and manganese by oxidation to MnO_4^-. Several improvements have been made in the procedure. In the original electrolysis, expense is saved by lessening the quantity of KI and increasing the KBr content of the anolyte. The sample of steel weighs 60–80 g., a current of 0·8 amp. is used and at least 20 amp. hr. of current. Frequently, drops of anolyte are tested to see that the pH is 6·8–7·0. A table is given showing the pH corresponding to various mixtures of phosphate buffer solutions. Before the electrolysis the sample should be heat-treated to make it hard, and the surface ground off. The anolyte is prepared from 1·5 kg. sodium citrate, 180 g. KBr, and 20 g. KI in 10 l. of water. The catholyte should be

10% $CuBr_2$ solution. The two solutions should be separated by a porous plate which should be dried and coated with agar-agar solution. Separate portions of the residue are treated (*a*) with a solution of 200 g. of $CuBr_2$ in 300 ml. of water or (*b*) a solution of 50 g. of glycerine in 300 ml. water. For the (*c*) reaction, take 50 ml. of $CuBr_2$ solution, and 0·45 ml. of 6N HCl, add a portion of the residue and pass purified nitrogen through the apparatus for 5 min. after uncondensed steam, used for heating, appears. Pour off the liquid and treat 2 min. more with 15 ml. of the $CuBr_2$ solution. Filter through a hardened filter and wash the residue with water, then several times with 10% Na_2CO_3 solution and finally with water. Full directions are given for determining aluminium, chromium, iron, manganese, and silicon in the residue. For the glycine separation, treat another sample of the residue with 30 ml. of the glycine solution for 5 min., evaporate the filtrate to dryness, fuse with a little $K_2S_2O_7$, take up with water and a little acid and determine the free MnO as MnO_4^-. The results of about 50 analyses are tabulated.

Influence of Crystal Orientation on the Oxidation at High Temperature of Iron and Copper. J. Bénard and J. Talbot. (Comptes Rendus, 1947, vol. 225, Sept 1, pp. 411–413). Variations in speed of oxidation in air at 850° C. of polycrystalline iron subjected to preliminary mechanical treatment were investigated. In the case of rolling it was observed that the speed of oxidation increased proportionately to the reduction in section. X-ray examination of the deformed metal showed that this variation correlated with the appearance of an orientated structure but was independent of the splitting of the crystals and of any disturbance within the lattice caused by cold work.—J. C. R.

Segregation Concentrations and Ghost Lines and Their Connection with Gas Evolution. R. Borione-Colas. (Bulletin du Cercle Études des Métaux, 1947, vol. 5, Dec., pp. 1–26). This paper is divided into three parts. In the first a review is presented of the various types of segregation that occur in steel ingots. The second part deals with a study of local segregations and blowholes in four 4-ton ingots of chromium–molybdenum–nickel steel. The gas in the blowholes was found to be almost pure hydrogen. Ghosts and blowholes occurred together as a result of gas evolution. The third part deals with gases evolved, which were CO and CO_2 resulting from the reduction of iron oxide by carbon, and hydrogen which was evolved during the cooling of the ingot, and their effect on the formation of segregations. The authors conclude that evolved gas, particularly hydrogen, is a principal cause of ghost lines.—J. C. R.

A Contribution to the Determination of Lattice Constants and X-Ray Stress Measurements with Coarse-Grained Materials. F. Lihl. (Archiv für Metallkunde, 1946, vol. 1, Oct., pp. 25–31). In the determination of lattice constants by back-reflection methods with a rotating camera, errors may be introduced owing to the coarseness of grain of the test sample. Results of tests are presented showing the error with the sample (*a*) fixed, and (*b*) scanning, and the camera rotating. It is concluded that scanning is necessary for reasonable accuracy. A proposed alternative procedure is to take a number of individual reflections and measure the mean displacement of the images from a datum live. The mean of 30–40 strong reflections, or 50–60 weak reflections, should be sufficient for an accurate result.—M. A. V.

A Magnetic Study of Phase-Change Processes in Iron–Silicon Alloys. K. M. Guggenheimer, H. Heitler, and K. Hoselitz. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., pp. 192–199).

Carbide and Oxide in Surface Zones of Carburized Alloy Steels. A. Hultgren and E. Hägglund. (Jernkontorets Annaler, 1948, vol. 132, No. 1, pp. 1–14). [In Swedish]. The authors' paper before the American Society for Metals has been given as a lecture to Svenska Metallografförbundet. (*See* Journ. I. and S.I., 1947, vol. 157, Nov., p. 470).—R. A. R.

The Transformations of Metallic Alloys in the Solid State. C. H. Desch. (Journal de Physique et le Radium, 1940, Series 8, vol. 1, Oct.–Dec., pp. 301–310). An account is given of the work of various investigators on the study of transformations of metallic alloys in the solid state.—J. C. R.

Anisothermal Formation of Bainite and Proeutectoid Constituents in Steels. L. D. Jaffe. (American Institute of Mining and Metallurgical Engineers, Technical Publication No. 2290 : Metals Technology, 1947, vol. 14, Dec.). The work described is a continuation of that reported by J. H. Hollomon, L. D. Jaffe, and M. R. Norton (*see* Journ. I. and S.I., 1947, vol. 155, Feb., p. 316). The author compares the transformations in specimens of 0·30% and 0·97% carbon steels when quenched directly from a metal bath, and when transferred to a second metal bath at a lower temperature before final quenching. The pro-eutectoid ferrite and carbide transformations are each approximately additive, at least up to 1% transformation. The bainite transformation is not additive, reaction at a high temperature tending to retard subsequent reaction at a low temperature. Increasing the molybdenum content or the austenite grain size of a hypo-eutectoid steel increases the bainitic hardenability.—R. A. R.

CORROSION

Chemical Research and Corrosion Control: Some Recent Contributions of a Corrosion Research Group. W. H. J. Vernon. (Journal of the Society of Chemical Industry, 1947, vol. 66, May, pp. 137–142). A survey is made of the work of the Corrosion Research Section of the Corrosion Research Laboratory (Department of Scientific and Industrial Research), Teddington, since 1939.—C. O.

Studies on the Solution Potential of Iron. R. Reiller. (Métaux, Corrosion, Usure, 1942, vol. 17, Feb., pp. 19–20 ; Mar., pp. 44–46). The conditions required for the accurate measurements of the solution potential of iron using a constant-flow Evan's cell are considered and an account is given of the reactions that occur in each compartment of the cell.—J. C. R.

Determination of Physical Chemical Factors in Stress Corrosion Cracking of Mild Steel. M. G. Winterstein, H. J. McDonald, and J. T. Waber. (Welding Journal, 1947, vol. 26, Dec., pp. 723-s–726-s). Progress in the study of the stress-corrosion-cracking of boiler steel at the Illinois Institute of Technology is reviewed. A new type of testing apparatus in which wire specimens were maintained under a uniform load while surrounded by the corrosive solution is described. A calomel half-cell was used for measuring the potential. The results obtained with a soft steel wire (carbon 0·060%) in a solution of calcium nitrate and ammonium nitrate and water are discussed. It was found that the removal and reintroduction of nitrogen respectively eliminates and restores the cracking tendency in mild steel.—R. A. R.

The Electrochemical Corrosion of Cast Iron Applied to Microscopical Metallography and to the Theory of the Action of Reagents. L. F. Girardet. (Association Technique de Fonderie, Journées de la Fonderie, 1945, Oct. 19–20, pp. 97–106). The mechanism of electrochemical corrosion which occurs when a polished cast-iron surface

is in contact with an electrolytic reagent is investigated, and its application to microscopical metallography is discussed.—J. C. R.

The Corrosion of Heating Surfaces in Boiler Plates: Further Studies in Deposit Formation. J. R. Rylands and J. R. Jenkinson. (Institution of Mechanical Engineers and Institution of Electrical Engineers, Feb. 20, 1948, Advance Copy). Corrosion is an important factor in the formation of deposits on the gas-swept heating surfaces of steam generating plant. The paper compares the behaviour of cast iron and steel under the corrosive attack of the sulphur acids occurring in boiler gases. Preliminary laboratory tests show a pronounced difference in behaviour of the two metals. Further investigation shows that cast iron has inherent properties which increase its resistance to corrosion over a wide range of conditions. These properties are shown to be linked with the silicon content of cast iron. Consideration is given to the influence of corrosion products, and of sulphurous acid. An explanation is offered of a number of observed phenomena in practice, including the puzzling "band corrosion" in air-heaters. This is shown to be a temperature and acid-concentration phenomenon. The paper ends with some comments on the modern practice of cleaning economizers and air-heaters by washing, and makes suggestions for the future guidance of designers.

Oxidation of Steel by Alternating Heat-Treatment Cycles. N. T. Belaiew and D. Séférian. (Métaux, Corrosion, Usure, 1942, vol. 17, Mar., pp. 41–44). A 10-mm. cube of steel was heated repeatedly from room temperature up to 850° C., and developed the shape of a Maltese cross. The successive passages through the γ-phase during 8 hr. heating and the α-phase on cooling, caused oxidation, scaling, and deep cracks. Each face of the cube comprised a number of layers which approximated to the number of heat-treatment cycles, and the layers, which formed a pyramid, were of even thickness.—J. C. R.

Thermogalvanic Corrosion. R. M. Buffington. (Corrosion, 1947, vol. 3, Dec., pp. 613–631). An analogy is given comparing thermogalvanic cells with thermocouples, and reversibility experiments are described. Thermogalvanic formulæ and calculations are presented, and factors affecting the corrosion are discussed.—R. L. B.

Corrosion of Reinforcing Steel in Cracked Concrete. B. Tremper. (Journal of the American Concrete Institute, 1947, vol. 18, June, pp. 1137–1144). Small concrete blocks containing steel wires and deformed bars were loaded as beams to produce cracks. After ten years' exposure corrosion of the steel was found for short distances close to the cracks, but it was not sufficient to be considered serious.

Recent Developments in the Use of Corrosion Inhibitors. J. T. Nicholson. (Corrosion, 1948, vol. 4, Jan., pp. 32–36). Methods of evaluating factors causing corrosion are described and recent developments in the use of inhibitors are discussed.—R. A. R.

Universal Photographic Recorder. I—Application to a Thermobalance for the Study of Corrosion in Gaseous Media. A. M. Dumez. (Métaux, Corrosion, Usure, 1943, vol. 18, Mar., pp. 50–55; Apr., pp. 68–76; May, pp. 97–100). A description is given of a photographic recorder that can be adapted for various purposes and of recording appliances that can be used with it. An account is included of its use with a thermobalance in studying corrosion in gaseous media. A bibliography of 49 references is appended.—J. C. R.

Metals and Men. (Lancet, 1948, vol. 254, Mar., 20, pp. 452–453). Surgical utilizations of bodily internal metallic plates and screws are referred to and the possibility that failures in some cases might have been due to unfavourable electrolytic action between bone and metal is mentioned. Stainless steel of the 19/9 type has been found to be the material most nearly meeting the requirements necessary for successful application.—J. R.

Chimney Liner Corrosion Resulting from Gas-Fired Furnaces. G. B. Johnson. (Corrosion, 1948, vol. 4, Jan., pp. 15–23). A report is presented on the attack by the products of combustion of gas-fired heating installations on chimneys lined with aluminium, Wilder Metal, and plastic coatings.—R. A. R.

Experiences in Conditioning Corrosive Army Water Supplies in New England. G. P. Loschiavo. (Corrosion, 1948, vol. 4, Jan., pp. 1–14).

Corrosion in Condensate Gas Wells. N. Hackerman and D. A. Shock. (World Oil, 1947, vol. 127, pp. 198, 200, 202, 204, 206: Chemical Abstracts, 1948, vol. 42, Feb. 10, 856). Observations are made on the corrosion of steel coupons exposed for periods ranging up to two months in three gas wells. One exhibited severe corrosive attack, a second gave some indication of corrosive effects, and the third showed practically no indication of corrosion.

Recent Developments in the Study of Cathode Protection. R. B. Mears. (Gas, 1947, vol. 23, pp. 42–45; Chemical Abstracts, 1948, vol. 42, Feb. 10, 856). The mechanism of cathodic protection is discussed. An anode from the surface being protected supplies current to that surface. The cathodes on the surface are polarized by the current flow. When their potentials have been raised by polarization until they just equal the open-circuit potentials of the most anodic areas, the entire surface of the specimen is at the same potential; hence no current flows and no corrosion occurs. In practice the determination of the required potential is not quite so easy. In the southern states, it has been found that an external current sufficient to raise the pipe/soil/copper-sulphate/copper potential from −0·85 to −0·90 V. is sufficient to prevent corrosion. The criterion most generally used in the north-eastern part of the United States is that of the polarization curve-break method. If the potential of a freely corroding metal surface is measured while an increasing amount of cathodic current is supplied from an external source, frequently there is no change in potential until the current density reaches some definite value. With further increase in current density the potential of the surface changes in an anodic direction. A third method consists in measuring the potential of the corroding article at an anodic area (as a corrosion pit) and at some adjacent cathodic or anodic area by means of two reversible half cells. When both areas are brought to the same potential, sufficient protective current has been supplied to yield cathodic protection. This method is not well adapted for use in installing cathodic protection of buried structures, but is useful in the cathodic protection of water tanks and chemical equipment.

Mechanism of Cathodic Protection. R. B. Mears. (Oil and Gas Journal, 1947, vol. 46, Dec. 6, pp. 77, 79–80, 82). The author discusses methods for determining the current density required for complete protection against corrosion, especially of pipe lines.

Prevention of Auto-Corrosion and Electrolysis of Underground Piping Systems. F. Guery. (Revue Générale de l'Électricité, 1947, vol. 56, Oct., pp. 401–411). The corrosion of underground piping by electrochemical action is discussed. Methods of prevention are dealt with, including the use of sheathing, insulated joints, and cathodic protection.

Relationship between the Corrosibility of Steels and the Structural Modifications Due to Welding and Oxygen Cutting. A. Leroy and D. Séférian. (Métaux, Corrosion,

Usure, 1942, vol. 17, Jan., pp. 1-11). An account is given of corrosion tests in H_2SO_4 and sea water on test-pieces of mild steel, 0·33% carbon steel, copper steel and chromium–copper steel, which had been welded or cut with oxygen. The latter were most deeply corroded in a zone parallel to the cutting line. Arc-welded specimens were corroded heavily near the weld, but gas-welded specimens showed large bands of varying corrosion. The specimens were also examined micrographically to determine the influence of structure on the resistance to corrosion.—J. C. R.

Inhibition of Steel Corrosion by Sodium Nitrite in Water. M. Cohen. (Journal of the Electrochemical Society, 1948, vol. 93, Jan. pp. 26–39). The effect of sodium nitrite on the corrosion of steel in water was studied. The concentration required to inhibit corrosion depended on the conditions of motion and temperature.—R. A. R.

Sodium Chloride *versus* Construction Materials—High-Silicon Irons. W. A. Luce. (Chemical Engineering, 1947, vol. 54, Nov., pp. 217–219). Examples are given of applications of Duriron (containing 14·5% of silicon) and Durichlor (14·5% of silicon plus 3% of molybdenum) where the metal has to resist attack by sodium chloride. —R. A. R.

A Note on the Preparation, Suspension, and Testing of Corrosion Specimens. W. Murray. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., p. 200).

Marine Exposures of Cementiferous Painting Schemes. K. A. Pyefinch. (Journal of The Iron and Steel Institute, 1948, vol. 158, Feb., pp. 229–235).

ANALYSIS

Recent Methods for the Determination of Oxygen, Hydrogen and Nitrogen in Iron and Steels and Their Main Applications. G. Chaudron. (Société Française de Métallurgie : Revue de Métallurgie, 1947, vol. 44, May–June, pp. 144–155). Recent methods for the determination of oxygen, hydrogen, and nitrogen in iron and steels are reviewed.—R. F. F.

Determination of Manganese in Steels. (0·1 to 0·01%). P. Rocquet. (Revue de Métallurgie, 1947, vol. 44, May–June, pp. 156–160). The Lingane and Karplus method of determining manganese is described and used as a standard of comparison for the more rapid colorimetric method advocated by the author. The procedure for the author's method is given in detail.—R. A. R.

The Determination of Oxygen in Steels by the Diffusion of Aluminium. J. Massinon. (Société Française de Métallurgie : Revue de Métallurgie, 1947, vol. 44, May–June, pp. 174–179). Tests on Gotta's method for the determination of oxygen in steels by the cementation of aluminium are described. An ordinary laboratory muffle furnace proved adequate for these tests, and the method of operation is described. Results obtained are given.—R. F. F.

The Art of Carbometry. F. S. Ellis and H. M. Lees. (Blast Furnace and Steel Plant, 1947, vol. 35, Nov., pp. 1357–1358). Determination of the carbon content of open-hearth steel by the measurement of some electrical property dependent on carbon content is discussed. Trustworthy specimens are of great importance in such applications, and the necessity for care in the selection, training, and instruction of the samplers is emphasized.—J. R.

Titration of Iron in High-Temperature Alloys. L. Silverman. (Steel, 1948, vol. 122, Jan. 26, pp. 66–68). A critical review is made of methods for the determination of the iron content of heat-resisting alloys containing cobalt, nickel, chromium, titanium, tungsten, and molybdenum, and a suggested procedure is detailed in which the solution, after removal of molybdenum by H_2S, is reduced with copper powder.—J. R.

Estimation of the Chief Elements in Steel by the Three-Line Method. J. Alexandre. (Groupement pour l'Avancement des Méthodes d'Analyse Spectrographique des Produits Métallurgiques, 6th Congress, June, 1946, pp. 25–36). The method depends on the determination of the index points, *i.e.*, concentrations of an alloying element such that the intensity of the line measured for that element equals that of selected lines of the iron spectrum. Using a condensed spark of the Feussner type and a medium dispersion spectrograph, suitable lines are tabulated for silicon, manganese, nickel, molybdenum, chromium, and vanadium with index points chiefly in the range 0·3–3%, rising to 7·5% for nickel. Either two steel samples are used, or one sparked with an aluminium counter-electrode, and details of both methods are given.—E. van S.

The Spectrographic Determination of Carbon in Steel. F. W. J. Garton. (Spectrochimica Acta, 1947, vol. 3, pp. 68–88). Spark spectra between a flat surface of a steel sample and a conical silver electrode were used in the quantitative determination of carbon using the line C 2296·9 and a large Littrow spectrograph. A preliminary investigation of the spark characteristics by means of a rotating mirror is described. In the range 0·2–1·0% the results were satisfactory, with a coefficient of variation of about 3%, but quenched carbon steels showed a higher carbon content than the same sample in the annealed condition. This effect is discussed, and also the difficulty of extending the method to low carbon contents, since the CO_2 content of the laboratory air is usually sufficient to show some carbon in the spectrum, and varies from day to day. Other alloying elements in steel can be determined from the same exposures, but the photographic technique is slightly different.—E. van S.

Investigation of an Analytical Technique Suitable for the Spectrographic Analysis of High-Speed Steels. G. Brucelle. (Groupement pour l'Avancement des Méthodes d'Analyse Spectrographique des Produits Métallurgiques, 8th Congress, 23–25 June, 1947, pp. 39–45). High-speed tool steels containing 11–20% of tungsten were tested using two electrodes of the sample, and a counter-electrode of copper, aluminium, or iron. The best results were obtained either with the two electrodes the same or with copper, which is therefore recommended as the best counter-electrode material. A controlled spark of the Feussner type was used and high self-induction. Typical results and calibration lines are given for silicon, chromium, molybdenum, vanadium, and titanium in the alloys ; the slope of the calibration line for vanadium is rather different from that for the other elements, giving a lower accuracy.—E. van S.

New System of Spectrographic Analysis. R. Ricard and A. Cornu. (Revue de Métallurgie, 1945, vol. 42, Dec., pp. 389–392). A new spectrograph is described which allows the comparison of the spectrum of the specimen with that of a standard test-piece.—R. F. F.

The Automatic Control of the Spectrographic Exposure. C. H. R. Gentry, D. Newson, and D. F. Rushman. (Journal of the Society of Chemical Industry, 1947, vol. 66, Sept., pp. 323–325). An electronic circuit for the automatic control of the sparking and exposure cycle in spectrographic analysis is described.—C. O.

Present State of Investigations in the Electric Steelworks of Ugine on the Spectrographic Analysis of Ordinary and Special Steels. R. Castro and J. M. Pheline. (Groupement pour l'Avancement des Méthodes d'Analyse Spectrographique des Produits Métallurgiques, 7th Congress, 21–23 Jan., 1947, pp. 25–49). For low-alloy

steels controlled spark excitation is used with two samples of the steel, or a spark between a flat surface and an aluminium electrode. Calibration is by comparison of the impurity line with a number of iron lines, and the accuracy obtained, measured by the standard deviation of 30 spectra on a single plate, ranges from 2–3% for chromium to 5–7% for silicon; manganese, nickel, and molybdenum have intermediate values. For stainless steels and high-chromium alloys controlled spark excitation was used, after results with A.C. arc had been found insufficiently reproducible. Cast samples are sparked with an aluminium electrode and calibration curves are given for silicon, manganese, nickel, chromium, molybdenum, titanium, and copper. The reproducibility is in general similar to that for ordinary steels quoted. For stainless steels containing tungsten, niobium, and tantalum a special method is being used, since no pure compounds of niobium or tantalum are available for standardization. The tungsten/iron ratio is determined spectrographically, followed by the chemical separation of the mixed oxides of the three elements; this enables the niobium plus tantalum to be determined by difference.—E. van S.

Note on the Simultaneous Determination of Vanadium and Titanium in Alumina or in Steel. J. Gillod. (Groupement pour l'Avancement des Méthodes d'Analyse Spectrographique des Produits Métallurgiques, 8th Congress, 23–25 June, 1947, pp. 123–124). The peroxides of titanium and vanadium, although similar in apparent colour in solution, have a marked difference in their absorption spectra, and it has been shown that the absorption spectrum of a mixture is similar to the summation curve of that of the two components. Thus by spectrophotometric measurements at 4600 and 5200 Å and a simple calculation, mixtures of the two peroxides in solution can be estimated with an accuracy approaching 2% of the amount present.—E. van S.

Spectrographic Estimation of Small Amounts of Copper in Iron and Steel. R. Castro and J. M. Pheline. (Spectrochimica Acta, 1947, vol. 3, No. 1, pp. 18–39: Groupement pour L'Avancement des Méthodes d'Analyse Spectrographiques des Produits Métallurgiques, 8th Congress, 23–25 June, 1947, pp. 47–59). Three methods, two spectrographic and one colorimetric, are described in this paper. Solutions are first prepared from 4 g. of steel, and the iron is removed by chloride extraction with ether until less than 0·2 g. of iron remains, this is then made up to precisely 0·2 g. in 50 ml. of solution containing 2 ml. of HNO_3. Ten drops are dried on a graphite electrode and arced with 10 amp. D.C. The spectrum is recorded, and the line Cu 3274 is used for a microphotometric determination of the copper/iron ratio. For routine tests a flat surface of the steel sample is sparked with an aluminium rod using a controlled spark generator and a step filter in front of the slit of the spectrograph. The index points are tabulated for the copper line and a number of iron lines covering the range of 0·02–0·5% of iron. An alternative technique for strip is described. The colorimetric method depends on the separation of copper as the sulphide with thiosulphate, which is dissolved in acid, buffered, and determined colorimetrically as the green complex with rubeanic acid (dithio-oxamide) using a red filter in any suitable colorimeter.—E. van S.

Spectrographic Determination of Aluminium in Metallic Oxide Residues. Application to the Determination of Oxygen in Special Steels. R. Castro and J. M. Pheline. (Comptes Rendus, 1947, vol. 225, Oct. 13, pp. 633–635). The method described consists of dissolving the steel in acid, fusing with ammonium bisulphate and adding a known quantity of cobalt sulphate. The mixture is dissolved and some drops are dried on a copper electrode heated to 120° C., and a spectrum is excited by a spark. The comparison of the relative intensities of the aluminium and cobalt lines with those obtained from spectra of synthetic solutions enables the quantitative determination of alumina to be made.—J. C. R.

Polarography. Cécile Roy-Pochon. (Chimie et Industrie, Technologie, 1944, vol. 52, pp. 91–94). Polarographic methods and apparatus are described.—R. F. F.

Purification of Mercury Used in Polarography. P. N. Terechtchenko. (Zavodskaya Laboratoriya, 1947, vol. 13, Mar., p. 384: [Abstract]. Chimie et Industrie, 1948, vol. 59, Jan., p. 50).—R. F. F.

Sulphur in Fuel Oil. K. R. Klumb. (Steel, 1948, vol. 122, Feb. 2, pp. 107, 138). The apparatus and procedure for a rapid combustion method of determining the sulphur in fuel oil are described.—R. A. R.

ECONOMICS AND STATISTICS

Some Technical Aspects of the Reconstruction Programme. T. P. Colclough. (Harold Wright Lecture: Cleveland Scientific and Technical Institution, Nov. 12, 1947: Iron and Steel, 1948, vol. 21, Feb., pp. 57–62). The recently announced reconstruction programme for the British iron and steel industry (White Paper, Cmd. 6811) is discussed with special reference to the technical aspects of the required increase in production.—R. A. R.

Possible New Zealand Base Metal Industries. P. A. Ongley. (New Zealand Engineering, 1947, vol. 12, Dec., pp. 1236–1242). The prospects of developing metallurgical industries in New Zealand for producing non-ferrous metals and iron are reviewed. Economically, titanium and vanadium would be the only products worth separating from the vast Taranaki iron-sand deposits, but electric smelting and direct reduction would overcome the iron-making difficulties. Readily usable limonite existing at Parapara could be supplemented with Taranaki pig iron.—R. L. B.

Modernization of the French Steel Industry. (Machines et Métaux, 1947, vol. 31, June, pp. 217–218). The modernization plans for the French steel industry are outlined.—R. F. F.

Economic and Social Importance of the Iron and Steel Industry in Belgian and Luxemburg Economy. P. Gillian. (Ossature Métallique, 1948, vol. 13, Jan., pp. 35–46). The important part played by the iron and steel industries of Belgium and Luxemburg in pre-war years in the economy of these countries is stressed. The factors that will govern their future importance are discussed.—J. C. R.

MISCELLANEOUS

The Design of Industrial Furnaces in Germany (British Zone). (British Intelligence Objectives Sub-Committee, 1948, Final Report No. 1601: H.M. Stationery Office). A report on German industrial furnaces after visits to 17 furnace builders and 20 installations is presented; all types used in steelworks, excluding the blast-furnace, are covered. No astounding novelties were encountered, but very modern designs were seen. Variations between plants are discussed, and design data are compared with working results in several cases.—R. A. R.

Heat Transfer in Industry. C. E. Lucke. (Mechanical Engineering, 1948, vol. 70, Jan., pp. 11-12). The collection and application of heat-transfer data and equations are discussed, and recommendations are made for the exchange of information on all phases of heat transfer in industry.—J. R.

Vacuum Degassing Tests on Non-Ferrous Metals in the Solid Phase Used in the Manufacture of Special Steels. J. Hochmann. (Société Française de Métallurgie : Revue de Métallurgie, 1947, vol. 44, May–June, pp. 161–173). Ferrous alloys and nickel, cobalt, chromium, manganese, and aluminium, were heated in a vacuum at temperatures of 600°, 800°, 1000°, and 1200° C. for between 30 min. and 1 hr. ; the total quantity of gases released was measured and compared with that remaining in the metals. The latter amount was determined by melting the metal in a vacuum.—R. F. F.

New Welsh Steel Plant. (Welding, 1948, vol. 16, Jan., pp. 3–6). A description is given of some of the buildings to be erected for the new steelworks of The Steel Company of Wales, Ltd., at Margam, in the construction of which there will be much welding.—R. A. R.

Inspection of Railway Locomotives and Rolling Stock. C. R. Mayo. (Engineering Inspection, 1947, vol. 11, Winter Issue, pp. 13–19). Experiences of railway locomotive and wagon inspectors are related.—R. A. R.

Electronic Devices in Industry. H. B. Cronshaw. (Instrument Practice, 1947, vol. 1, July, pp. 338–344, 352 ; Sept., pp. 419–424 ; Oct., pp. 455–458). An account is given of the applications of electronic tubes for (*a*) rectification, inversion, and frequency changing of electric currents, (*b*) radiofrequency heating, (*c*) high-frequency transmission, (*d*) measurement and control, (*e*) electrostatic cleaning, (*f*) lighting and X-rays.—C. O.

Safety of Operation of Diesel Locomotives in Mines. A. Glatz and V. Sládeček. (Bansky Obzor, 1947, vol. 1, No. 8–9, pp. 113–117). [In Czech]. Experiments were carried out at the Ostrava Mine Testing Station to determine the safety of operation of explosion and constant-pressure Diesel locomotives for use in mines. —M. A. V.

BOOK NOTICES

BALLARD, W. E. "*Metal Spraying and Sprayed Metal.*" Third Edition based on previous editions by E. C. Rollason and by T. Henry Turner and N. F. Budgen. 8vo, pp. xvi + 362. Illustrated. London, 1948 : Charles Griffin and Co., Ltd. (Price 32*s.*).

The first textbook in the English language on metal spraying was written by T. Henry Turner and N. F. Budgen in 1926. In 1939 it became necessary to reissue the volume and the work of revision was undertaken by E. C. Rollason, but in five years, owing to the importance of the subject, this second edition was exhausted. The present edition has been brought up to date, but in order to keep the volume within reasonable size and yet expand certain sections, it has been necessary to delete the descriptions of the historical development of metal spraying, and those interested in the history of the process are recommended to consult the previous editions. The contents of the present work are as follows : (1) Introduction ; (2) The Modern Molten-Metal Process ; (3) The Modern Powder Process ; (4) Wire-Spraying ; (5) Working the Metal-Spraying Process ; (6) Preparation of Surfaces for Metal Spraying ; (7) Installation of Plant and Subsidiary Apparatus ; (8) Special Processes ; (9) Nature of Sprayed Metal ; (10) Properties of Metal-Sprayed Surfaces ; (11) Comparison of Metal Spraying with Other Methods of Protection and Deposition; and (12) Applications of the Metal-Spraying Processes. A number of useful tables are appended.—R. E.

HIMUS, G. W. "*The Elements of Fuel Technology,*" 8vo, pp. xvi + 506. Illustrated. London, 1947 : Leonard Hill, Ltd. (Price 42*s.*).

Dr. Himus will be well remembered as joint author with the late Prof. W. A. Bone, of "Coal : Its Constitution and Uses." The present work differs from its predecessor in that it is written rather more from the point of view of the practical user, and due prominence is accordingly given to the technological and economic aspects of the subject, especially as they affect the British user. The subjects covered include the nature, economic geology and utilization of coal ; the manufacture of solid, liquid, and gaseous fuels from coal ; fuel oils ; combustion and firing of all types of fuel ; and fuel economy in furnace practice. A minor criticism is that a reference appears on the contents page to "fuel in relation to the manufacture of iron and steel," under the unexpected chapter heading of "Domestic Heating," but no remarks on this subject could be found in the chapter in question. Nevertheless, much of the work is of direct interest to the metallurgist, notably the chapters on the manufacture of metallurgical coke, and the manufacture and use of producer gas. Taken as a whole, the book is remarkably complete and self-contained, and is adequately, but not excessively, annotated with references to the literature. It should prove a most valuable addition to the fuel technician's library.—M. A. V.

KLINGENDER, F. D. "*Art and the Industrial Revolution.*" 8vo, pp. xiii + 232. Illustrated. London, 1947 : Royle Publications, Ltd.

This interesting book deals with the influence of the industrial revolution upon the arts. Well-known artists who painted industrial subjects of the period concerned, such as Joseph Wright of Derby and his contemporaries, the Swedish court painter Pehr Hilleström and the Belgian Léonard Defrance (who, by the social aspect of his paintings, was a forerunner of Meunier), are given the prominent place due to them. The reflection of social and economic changes upon poetry and economic thought complete the description of the influence of the industrial revolution noticeable in the various aspects of life. The author is mainly concerned with the period of his subject, the eighteenth and nineteenth centuries, but the art of technical draughtsmanship is traced back by him to Leonardo da Vinci's drawings. This volume should rank with the great technical works of the sixteenth century, such as Georgius (not Gregorius!) Agricola's "De re metallica," and "Vannoccio Biringuccio's "Pirotechnia," first edited in 1540 (translated by C. St. Smith and M. T. Gnudi, New York, 1942) as a volume of historic interest.—H. R. SCHUBERT.

SILMAN, H. "*Chemical and Electroplated Finishes—The Protective Treatment of Metals,*" 8vo, pp. 432, London, 1948 : Chapman and Hall, Ltd. (Price 30*s.*).

In the manufacture of metal articles a surprisingly high proportion of the total effort is devoted to protective and decorative finishing operations. Prevention of corrosion is perhaps more important, but attractive appearance is also necessary for competitive sales ; a single process combining both objectives is thus desirable. There has been in the past a tendency to regard such methods as an art or craft, rather than part of the production sequence ; this phase is happily passing.

The book under review is addressed to those requiring an authoritative broad survey of the scope and present position of metal finishing, in sufficient detail to plan these processes as an integral part of a production schedule. It deals only with those chemical and electroplating processes carried out in aqueous solutions, together with their ancillary processes, and thus claims to be neither a textbook of electroplating principles nor a working manual of metal finishing. The author has had exceptional opportunities for observing and evaluating the numerous processes employed or advocated in this country and the United States. This information he has set out in a volume the easy style and clear treatment of which conceal the critical selection and balanced attention given.

The book opens with a short but admirable review of the theory of metallic corrosion (29 pages) and proceeds to a description (127 pages) of the preliminary descaling, polishing, degreasing, and cleaning processes, on the success of which the effectiveness of subsequent steps so much depends. This includes a concise and masterly review of the principles of aqueous degreasing and a wisely cautious description of electrolytic methods of brightening—to call these processes electropolishing is liable to raise false hopes. Non-electrolytic chemical methods of metal finishing are then described (41 pages), including an impartial but authoritative review of phosphatizing treatments for steels ; these have attained, under various proprietary names, considerable importance in recent years. About a third of the total volume (157 pages) is then devoted to a survey of electroplating plant and processes for deposition of all commonly plated metals. In this section, and indeed throughout the book, the emphasis is given to processes which can be planned and carried out as mechanical engineering operations, thus avoiding the variability of the hand operative, however skilled or experienced. For a similar reason, no doubt, the excellent illustrations are in general of large and expensive plant, justification for which must be its standardized production and high output. A section on the specialized treatments for light alloys, both electrolytic and non-electrolytic, follows (28 pages) ; these processes had risen during the war years to an importance almost equal to those for steel, and they may yet regain this position. The short section (13 pages) on the testing of the various coatings is well set out, but is perhaps unduly brief ; it is essential that the buyer and even the user should be able to assure himself that metal finishes are in fact adequately protective as well as attractive. This slight note of criticism must not be allowed to detract from commendation of a book having a breadth of view and giving such wide factual information that it is one of the most important available. Some indication of its value is expressed in the hope that a companion volume dealing with organic finishes, vitreous enamelling, and other metal finishing processes will be forthcoming.

The book is excellently produced and printed. The only serious error is perhaps the statement (p. 99) that electrobrightening of stainless steel is carried out at 5 amps./sq. ft., whereas 5 amps./sq. in. is unfortunately more probable.—G. E. GARDAM.

SIMONS, E. N. "*Iron Simply Explained.*" 8vo. pp. viii + 203. Illustrated. London, 1947 : Paul Elek. (Price 12*s.* 6*d.*).

This book is intended to provide a compendium of simplified information on the manufacture and properties of pig iron, wrought iron, and cast iron.—R. E.

NEW PUBLICATIONS

AKIMOV, G. V. "*Collected Papers on Rapid Methods for Protecting Parts from Corrosion.*" 8vo, pp. 163. Illustrated. Moscow and Leningrad, 1946 : Academy of Sciences of the U.S.S.R. (Price 10.55 roubles). [In Russian].

AKIMOV, G. V. "*Essentials in the Study of the Corrosion and Protection of Metals.*" 8vo, pp. 463, with 371 illustrations. Moscow, 1946 : Metallurgizdat. (Price 20 roubles). [In Russian].

AMERICAN IRON AND STEEL INSTITUTE. "*Steel Products Manual.*" Section 20. "*Wrought Steel Wheels.*" 8vo, pp. 87. New York, 1947 : The Institute.

BATELLE MEMORIAL INSTITUTE. "*Steel and Its Heat Treatment.*" 5th Edition, 8vo. Vol. I "*Principles.*" Pp. 489. (Price $6.00). Vol. II pp. 293. (Price $4.00). New York : John Wiley and Sons, Inc.

BRITISH STANDARDS INSTITUTION. B.S. 499 : Part 2 : 1948. "*Glossary of Welding and Cutting Terms.*" Part 2. "*Terms Relating to Weld Imperfections Appropriate for Radiographic Examination.*" 8vo, pp. 17. London, 1948 : The Institution. (Price 2*s.* 6*d.*).

BRITISH STANDARDS INSTITUTION. B.S. 1121 : 1948. "*Methods for the Analysis of Steel.*" Part 2. "*Nickel in Permanent-Magnet Alloys.*" 8vo, pp. 7. (Price 1*s.*) ; Part 3, "*Tungsten.*" 8vo, pp. 7. (Price 1*s.*). Part 4. "*Aluminium in Permanent Magnet Alloys,*" 8vo, pp. 7. (Price 1*s.*) ; Part 5. "*Copper in Permanent Magnet Alloys.*" 8vo, pp. 6 (Price 1*s.*). London, 1948 : The Institution.

CARSLAW, H. S. and J. C. JAEGER. "*Conduction of Heat in Solids.*" 8vo, pp. vii + 386. Oxford, 1947 : Clarendon Press ; London : Oxford University Press. (Price 30*s.*).

HALL, J. D. "*Industrial Applications of Infrared.*" New York : McGraw-Hill Book Co., Inc. (Price $3.50).

HEUMANN, G. W. "*Magnetic Control of Industrial Motors.*" 8vo, pp. 589. Illustrated, New York : John Wiley and Sons, Inc. (Price $7.50).

HOTTMAN, W. J. and W. C. KEIL. "*Temper Brittleness in Boiler Steels and Rail Steels.*" Pp. 66. Golden, Colo., 1947 : Colorado School of Mines. (Price $1.00).

IRON AND STEEL INSTITUTE, Special Report No. 39. "*Reports of the Affiliated Local Societies.*" 4to. pp. iv + 80. Illustrated. London, 1947 : The Institute. (Price 5*s.* Members, 10*s.* Non-members).

JUDGE, A. W. "*Engineering Materials.*" Vol. 3. 8vo, pp. 624. London : Sir Isaac Pitman and Sons, Ltd. (Price £2).

RICHTMYER, F. K. and E. H. KENNARD. "*Introduction to Modern Physics.*" (International Series in Pure and Applied Physics). Fourth Edition. 8vo, pp. xvii + 759, with 241 Illustrations. New York, 1947 : McGraw-Hill Book Co., Inc. ; London : McGraw-Hill Publishing Co., Ltd. (Price 36*s.*).

SQUIRE, A. "*Powder Metallurgy.*" 8vo, pp. 183. New York, 1947 : Mapleton House. (Price $8.00).